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PASSIVE ENVIRONMENTAL ASW PREDICTION SYSTEM (PEAPS)

Michael Edward Beckes

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

PASSIVE ENVIRONMENTAL ASW PREDICTION SYSTEM (PEAPS)

by

Michael Edward Beckes
Nicholas Pegau Burhans
Robert Edgar Gump

March 1975

Thesis Advisors: A.B. Coppens
D.E. Harrison Jr

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The program was written for a programmable desk-top calculator for immediate deployment and operational testing

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(20. ABSTRACT Continued)

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Passive Environmental ASW Prediction System (PEAPS)

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ABSTRACT

PEAPS (Passive Environmental ASW Prediction System) is a relatively unsophisticated model which accepts input source and receiver parameters and then predicts sound propagation characteristics in an ocean environment, the corresponding transmission loss, and the probability of detection. The program was written for a programmable desk-top calculator for immediate deployment and operational testing aboard small ASW platforms. The program is also available in a form suitable for larger computers.

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TABLE OF SYMBOLS

SYMBOL	DEFINITION
A	The absorption coefficient (dB/yd) derived from the input source frequency.
BMA	The angle of incidence below which the bottom loss becomes constant (determined by the input source frequency and bottom type).
BO	The intercept used in the bottom loss equation.
B1	The slope used in the bottom loss equation.
CD1	Surface depth - the first point entered by the operator (always 0.0).
CD2	The depth of the sonic layer (if no sonic layer exists, then CD2 = CD1).
CD3 to CD5	The depths of the critical points (those points where the gradient of the speed of sound changes sign or becomes zero) between CD2 and the bottom.
CD6	The bottom depth.
CS1 to CS6	The sound speeds corresponding to the critical depths CD1 to CD6.
CZMAX	The maximum range of the first convergence zone annulus.
CZMIN	The minimum range to the first CZ annulus.
CZSTOP	The incremented stopping range for the CZ segment of the program.
CZSTRT	The incremented starting range for the CZ segment of the program.
DFL	The diffractive loss out of the surface duct; used in the surface duct segment of the program.

SYMBOL	DEFINITION
DR	The horizontal range increment used while ray tracing = $5[D(i)-D(i-1)]^{1/2}$ where D(i) is the SSP depth below, and D(i-1) that above the ray depth.
DRPERM	Range increment in the TL/PD program = 2000 yards; used outside the CZ annulus.
DRWRK	The working range increment used by the transmission loss program; = DRPERM outside the CZ annulus, = 0.1 the annulus width inside the CZ annulus.
DTH	The angle increment to be added to THMIN (input by the operator when MODE = 2).
D1 to D15	The input depths from the BT trace.
G	The sound speed gradient in the water column segment in which the ray is being traced.
IBB	The bottom-bounce propagation-path indicator.
IBT	The input bottom type indicator (1 to 9) which is converted to a factor (BT) used in the bottom-bounce segment of the TLOSS program.
ICZ	The convergence-zone propagation-path indicator.
ICZRC	The CZ range increment counter.
IDSC	The deep sound-channel propagation-path indicator.
IFOM	The input figure of merit.
IPLOT	The plotting indicator for the ray trace program used during MODE = 0. 0 = the ray trace is to be plotted. 1 = the ray trace is not to be plotted.
IRAP	The indicator for reliable acoustic path.

SYMBOL	DEFINITION
ISD	The indicator for surface-duct propagation path.
ISS	The input system sigma.
IWH	The input wave height (in feet).
N	The number of bottom bounces being considered by the bottom bounce segment of the program.
NG	The number of critical gradient sections in the sound speed profile.
NPTS	The number of input points from the BT trace.
MODE	The mode indicator for the ray trace program. 0 = automatic ray trace, compute, and plot. 1 = automatic ray trace, compute no plot. 2 = operator enters the source emission angles to be plotted by the ray trace program, then a Mode 1 computation to determine values needed for follow-on programs.
R	The horizontal range of the ray that is being traced (in ft) and the TL/PD range (in yards).
RD	The input receiver depth (in feet).
RADINV	The inverse of the radius of curvature for a ray as it is traced through a vertical section of the water column.
RDR	A derived factor used in the ray trace program (RADINV * DR).
RL2	The square of the cutoff range for the reliable acoustic path (RAP) portion of the program.
RMAX	The derived maximum range to be considered in the transmission loss/probability of detection program (dependent on IFOM).

SYMBOL	DEFINITION
RPT	The transition range used in the deep-sound-channel segment of the program.
RS	The derived skip distance used in the surface-duct segment of the program.
RT	The derived transition range used in the surface-duct segment of the program.
SD	The input source depth, in feet.
SE	The derived signal excess (SE = STL - IFOM).
SF	The input source frequency, in Hertz (Hz).
SS	Speed of sound.
SSL	The derived sea surface loss used in the surface duct segment of the program.
STL	The cumulative transmission loss from the existing transmission paths at a particular range from the source.
SV	The derived speed of sound at the source.
S1 to S15	The derived speed of sound corresponding to the input data from the BT trace.
TH	The angle the ray makes with the horizontal as it is being traced.
THBB	The derived minimum emission angle from the source that will result in a bottom bounce ray.
THBL	The angle used to determine the bottom loss in the bottom bounce segment of the program.
THMAX	The maximum ray emission angle from the source entered by the operator when MODE = 2.
THMIN	The minimum ray emission angle from the source entered by the operator when MODE = 2.

SYMBOL	DEFINITION
THP	The approximate minimum source emission angle that will produce a convergence zone ray. Used as a starting point in the automatic modes (MODE = 0 or 1) to determine CZMIN by iterative ray tracing.
THPP	The approximate THBB used in the automatic modes as a starting point for iterative ray tracing to determine THBB.
TL	A transmission loss storage location.
WRKNG	Storage registers used in several portions of the programs for temporary storage.
Z	The depth of the ray being traced, measured from the source depth.

I. INTRODUCTION

A. BACKGROUND

Shore-based prediction systems rely on complex acoustic models which require large computers and relatively long computation times. Their predictions are based on historical meteorologic and oceanographic data for regions in which environmental conditions are assumed to be homogeneous. These systems use a single level of sonar performance as the basis for all range predictions. The value of such systems lies in their use as research tools and for pre-deployment planning: they can be considered to be strategic systems.

With the advent of the programmable desk-top calculator comes the possibility that a simple acoustic prediction model can be placed on board anti-submarine warfare (ASW) platforms. This makes it possible for the ASW platofrm to take advantage of on-scene bathythermographic (BT) data to obtain current range predictions based on the output of the platform's own sensors. In addition, an on-board system enables the ASW platform to obtain predictions under all electronic emission control (EMCON) conditions. The programmable desk-top calculators make possible environmental predictions at the tactical level.

B. PEAPS

1. Description

PEAPS (Passive Environmental ASW Prediction System) was designed for use in any programmable desk-top calculator or general-purpose computer with sufficient capacity for the program.

The system is composed of four sub-programs: a speed of sound profile (SSP) generator, a ray trace generator, a transmission loss (TL) generator, and a probability of detection (PD) generator. The SSP and ray trace generators are combined as an SSP/Ray Trace program; the TL and PD generators are combined as a TL/PD program. These sub-programs are described in detail in subsequent chapters.

2. Assumptions and Constraints

The system was written originally in a machine language for use on a small capacity, programmable, desk-top calculator (the Hewlett-Packard Model 9810A with expanded storage). The hardware used to develop PEAPS is described in Appendix A. Total program capacity of the calculator was 2036 program steps with 100 data-storage registers. This calculator was used because it was relatively inexpensive and readily accessible; it was reasoned that if a simple working model could be designed on a small-capacity, programmable calculator, more sophisticated models would be possible on larger programmable calculators.

PEAPS is a relative unsophisticated system which uses approximation techniques to compute transmission losses

under the assumptions of a flat-bottomed ocean and phase incoherent interference. Lateral variations in vertical temperature profiles are neglected. Speed of sound profiles are approximated by straight-line segments, with storage available for fourteen segments (fifteen input points) and five smoothed gradients. When available to the user deep ocean historical data may be incorporated into the input, but such data are neither stored nor generated internally. The specific assumptions and constraints used in each sub-program are described in the subsequent chapter which deals with that sub-program.

General worksheets for PEAPS have been designed to guide the operator through the sequence of steps required to generate output (Appendix B).

Operator note sheets also have been written in outline form to describe the use of the individual sub-programs of the system and to assist the operator when problems and questions arise (Appendix C).

II. SPEED OF SOUND PROFILE (SSP) GENERATOR

A. PURPOSE

The speed-of-sound generator produces a plot of sound speed versus depth for inputs from a bathythermograph (BT) trace. The data are then searched for critical points which are stored for subsequent use by the ray trace and transmission loss (TL) programs. A critical point is a point on the sound speed profile where the gradient of the sound speed changes sign or becomes zero. All sound-speed points are stored for use in the ray trace sub-program.

B. INPUTS

Figure 1 shows the SSP portion of the operator's worksheet. The operator manually inserts the BT data from the worksheet into the calculator programmed for SSP/Ray Trace. As indicated, the data entered on the worksheet are the number of BT points to be entered, and the depth (ft), temperature (°F), and salinity (ppt) of each input point; if salinity is unknown and historical salinity data are unobtainable, a value of 35 parts per thousand (ppt) is entered. If the bottom depth is greater than that of the BT trace and historical data are not available, it is recommended that the operator enter the last BT temperature as the bottom temperature. This will produce a profile for constant temperature from the last BT point to the bottom. If tables of historical salinities and temperatures-versus-depth

PEAPS OPERATOR WORKSHEET

(See PEAPS Operator Note Sheets)

BT Information DTG: ________________ Z _____

Location: ________________ N/S ___, ____________________ E/W ____

1. Turn the calculator and plotter on. "LOAD" the SSP/Ray trace program cards. Put the plotting paper on the plotter and set the "GRAPH LIMITS" of the plotter.

2. Press "STOP, END, CONTINUE" (this sequence is used when a new SSP is to be generated.

Note 1: If you enter an erroneous value:

a. If you have not pressed "CONTINUE", press "CLR X", then enter the correct value.

b. If you have pressed "CONTINUE", you must re-enter all the points again; press "GO TO, LABEL, A", then continue with Step 3 below.

3. Press "CONTINUE".

4. SSP inputs: ENTER number of BT points (15 maximum) _____
Press "CONTINUE" after each value is entered to advance the program

Point	Input Depth (ft)	Input Temp (°F)	Input Salinity (ppt)	Output Speed of Sound (ft/sec)
1	0.0			
2				
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
10				
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
15				

FIGURE 1

for the oceanic area of interest are available to the operator, then use Section G of the Operator Note Sheets (Appendix G) to merge the historical and on-scene BT data for improved accuracy.

C. MODEL

The basic physical concepts of sound transmission are fairly simple, but computation of the sound speed for the ocean is rather complex because of the varying physical properties of sea water. The computation of sound speed from empirical relations based upon laboratory measurements began in the early 1950's (Del Grasso, 1952; Wilson, 1960). Attempts to record accurate hydrographic data while electronically measuring the sound speed were successful in the early 1960's (Hays, 1961; Mackenzie, 1961). For these latter experiments, a computed sound speed was obtained based on three measured parameters: temperature, salinity, and depth. The results were then compared with the electronically-recorded sound speeds. These observations resulted in either slight modification of the coefficients in existing equations or the development of new polynomial equations (Wilson, 1960; Leroy, 1968; Frye and Pugh, 1971; Anderson, 1971; Del Grasso, 1972). From the results obtained by these experimenters, the variation of sound speed versus temperature, salinity, and depth can be approximately represented as indicated in Table I.

Approximately 99% of all sea water falls within the temperature range -3°C to +30°C and the salinity range 33 to

TABLE I

Variations of sound speed caused by variations in temperature, salinity, and depth. A variation of one parameter signifies that the other parameters are held constant: temperature at 0°C, zero depth, salinity at 35.00 ppt.

Temperature (°C)	Sound Speed Change
0 - 10	4.5 (meters/sec)/°C
10 - 20	3.0 (meters/sec)/°C
20 - 30	2.0 (meters/sec)/°C
Salinity (ppt)	
33 - 35	1.55 (meters/sec)/ppt
35 - 37	1.25 (meters/sec)/ppt
Depth (meters)	
0 - 10,000	0.017 (meters/sec)/meter

37 ppt (Montgomery, 1958; Frye and Pugh, 1971). Thus, thermal gradients are usually much more significant than salinity gradients in sound speed computations; so that the temperature-depth relation is a factor which must be considered in greatest detail in any sound propagation model.

Because the Frye and Pugh equation [1] for sound speed is dominated by temperature terms and requires relatively few program steps compared with other speed of sound equations, it was used in the sound speed profile sub-program. The equation was modified to use the approximation

$$\frac{\Delta SS}{\Delta Z} = \frac{\Delta SS}{\Delta P}\frac{\Delta P}{\Delta Z} \doteq 0.1\ \frac{\Delta SS}{\Delta P}$$

for the speed of sound SS in meters/sec, the pressure P in bars (gage pressure), and the depth Z in meters. The resulting equation is

$$\begin{aligned} SS = {} & 1449.3 + 1.5848 \times 10^{-2}Z + 1.572 \times 10^{-7}Z^2 \\ & - 3.46 \times 10^{-16}Z^4 + 4.587T - 5.356 \times 10^{-2}T^2 \\ & + 2.604 \times 10^{-4}T^3 + 1.19(S - 35) + 9.6 \times 10^{-2}(S - 35)^2 \\ & + 1.354 \times 10^{-5}T^2Z - 7.19 \times 10^{-9}TZ^2 \\ & - 1.2 \times 10^{-2}(S - 35)T \end{aligned}$$

where SS = sound speed in meters/sec

Z = depth in meters

T = temperature in °C

S = salinity in ppt (parts per thousand).

The SSP sub-program converts the input data to MKS units for use in the above equation and then converts the resultant sound speeds to feet/sec for use in subsequent routines.

The above equation is relatively inaccurate in areas where salinity exceeds 36.6 ppt: Frye and Pugh claim accuracy only to 36.6 ppt and are presently working to extend the domain of their equation.

D. OUTPUT

The calculator prints the input data and the corresponding sound speeds on tape (Fig. 2), makes a plot of sound speed versus depth (Fig. 3), and refers the operator to Operator Note 2 for ray trace preparation (see Appendix C).

Figure 2. Sample Speed of Sound Profile generator printer input/output.

```
SSP
SEE NOTE 1

NR PTS
          15.00*
DEPTH
           0.00*
TEMP
          58.60*
SALIN
          35.00*
SPD
        4941.76

DEPTH
         120.00*
TEMP
          58.60*
SALIN
          35.00*
SPD
        4943.64

DEPTH
         175.00*
TEMP
          57.00*
SALIN
          35.00*
SPD
        4935.15

DEPTH
         200.00*
TEMP
          56.00*
SALIN
          35.00*
SPD
        4929.58

DEPTH
         225.00*
TEMP
          54.00*
SALIN
          35.00*
SPD
        4917.78
```

```
DEPTH
         400.00*
TEMP
          50.50*
SALIN
          35.00*
SPD
        4898.36

DEPTH
         650.00*
TEMP
          47.90*
SALIN
          35.00*
SPD
        4885.12

DEPTH
         870.00*
TEMP
          47.30*
SALIN
          35.00*
SPD
        4884.56

DEPTH
         900.00*
TEMP
          47.70*
SALIN
          35.00*
SPD
        4887.76

DEPTH
        1075.00*
TEMP
          46.50*
SALIN
          35.00*
SPD
        4882.36
```

```
DEPTH
        1100.00*
TEMP
          45.80*
SALIN
          35.00*
SPD
        4877.91

DEPTH
        1300.00*
TEMP
          45.00*
SALIN
          35.00*
SPD
        4875.51

DEPTH
        1380.00*
TEMP
          44.50*
SALIN
          35.00*
SPD
        4873.26

DEPTH
        1500.00*
TEMP
          43.70*
SALIN
          35.00*
SPD
        4869.49

DEPTH
        7500.00*
TEMP
          43.70*
SALIN
          35.00*
SPD
        4966.70

SEE NOTE 2
```

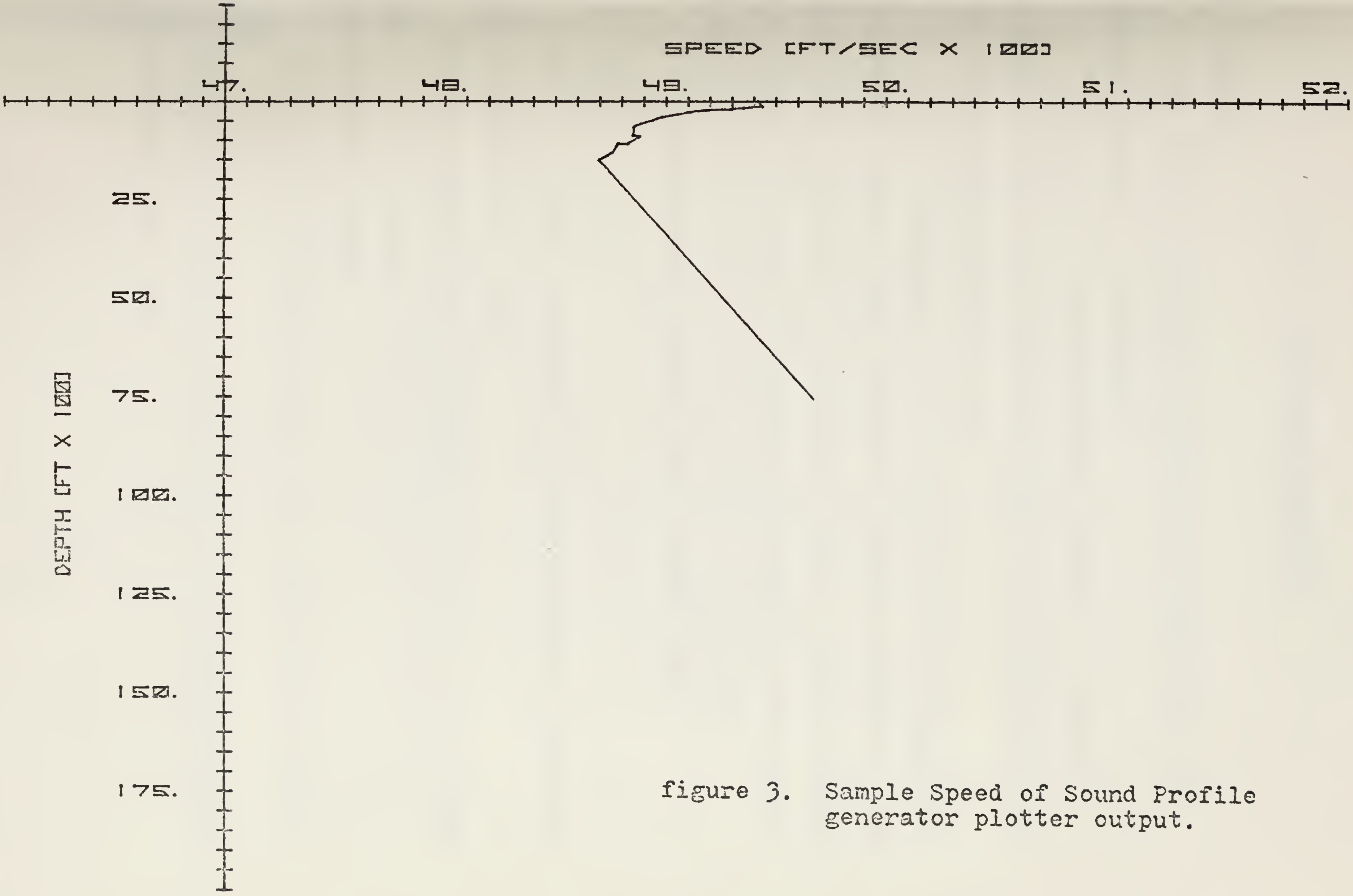


figure 3. Sample Speed of Sound Profile generator plotter output.

III. RAY TRACE GENERATOR

A. PURPOSE

A ray trace sub-program included in PEAPS makes the following tests and decisions:

1. inspect the speed-of-sound profile to determine whether the characteristics necessary for convergence zone propagation are present or not;

2. if CZ conditions exist, determine the maximum and minimum CZ ranges, where minimum CZ range is defined as the range from the source to the inner limit of the CZ annulus and maximum CZ range is defined as the range to the outer limit of the CZ annulus (Fig. 4), and in any event;

3. determine the minimum bottom bounce angle.

B. MODES

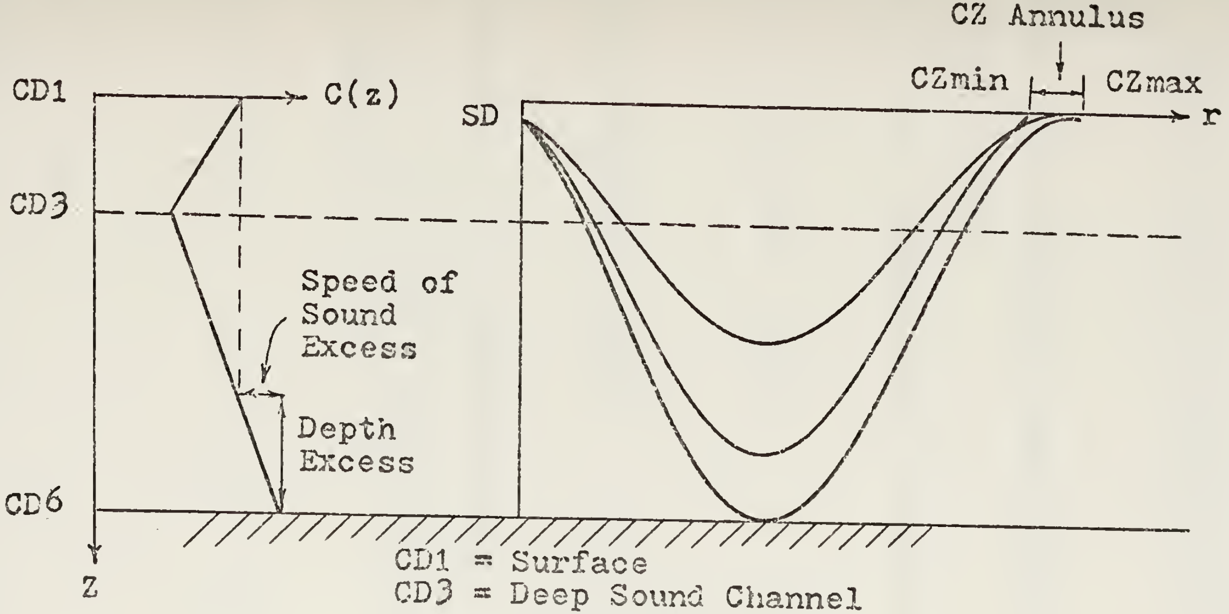
The ray trace sub-program has three modes of operation designated by 0, 1, and 2.

Mode 0 automatically determines and plots the limiting rays of the convergence-zone ray-family and stores the corresponding ranges.

Mode 1 is the same as Mode 0, but omits the ray trace plot.

Mode 2 gives a plot of the operator's input ray-family followed by a Mode 1 run.

figure 4. Convergence Zone Path



CD1 = Surface
CD3 = Deep Sound Channel Axis Depth
CD6 = Bottom Depth
SD = Source Depth

C. INPUTS

The operator enters the Mode number and source depth from the ray trace portion of the worksheet. If Mode 2 is selected, he must also enter twice the maximum and minimum emission angles and twice the desired increment in emission angle between successive rays[1] (Fig. 5).

D. MODEL

The ray trace generator uses Snell's Law in a small angle approximation.

Snell's Law for rays can be written as

$$\Delta r = R(\sin\theta 2 - \sin\theta 1)$$

and

$$\Delta Z = R(\cos\theta 1 - \cos\theta 2)$$

where the geometry is suggested in Fig. 6. Elimination of θ2 gives the range-depth equation in terms of the initial angle of depression,

$$\Delta Z1 = R\cos\theta 1 - R[1 - (\sin\theta 1 + \frac{\Delta r}{R})^2]^{\frac{1}{2}} \qquad (1)$$

---

[1] See Section B of Note 2 in the Operator Note Sheets (Appendix C).

Note 2: Change the plotting paper on the plotter. Enter the ray trace program MODE indicator.

MODE: _____
0 = Automatic compute and plot
1 = Automatic compute, no plot
2 = Manual inputs for plotting, Automatic compute.

If a ray trace input error is made, press "GOTO, LABEL, B, CONTINUE", then input the MODEL indicator and ray trace data again. (This sequence is used to generate a new trace using the old SSP data)

Press "CONTINUE"

4. Ray trace inputs:
Press "CONTINUE" after each input to advance the program.

Source Depth: ___________(ft)

If Mode 2 is used:

Minimum Ray Angle x 2: __________(degrees)

Angle Increment x 2: __________(degrees)

Maximum Ray Angle x 2: __________(degrees)

Note 3: If, while in Mode 0 and after the bottom limiting ray has been drawn, a channelled ray is drawn to the plot's range limit; see Operator Note sheet section Note 2E.
Change the plotting paper on the plotter. Press "STOP, END". LOAD the TLOSS/PD program cards. Press "STOP,END". (The "STOP, END" sequence is used when a TLOSS/PD input error is made, or a new TLOSS/PD plot is to be generated based on the old SSP/Ray trace data.)

5. TLOSS/PD inputs:
Press "CONTINUE" after each input to advance the program.

Press "CONTINUE"

Source Frequency: ____________(Hz)

Figure of Merit (FOM):________(dB)

System Sigma: ________(use 10 if unknown)

Wave Height: 0 1 2 3 4 5 6 7 8 9 10 11 12 (ft)

Receiver Depth: ________(ft)

Bottom Type: 1 2 3 4 5 6 7 8 9

FIGURE 5

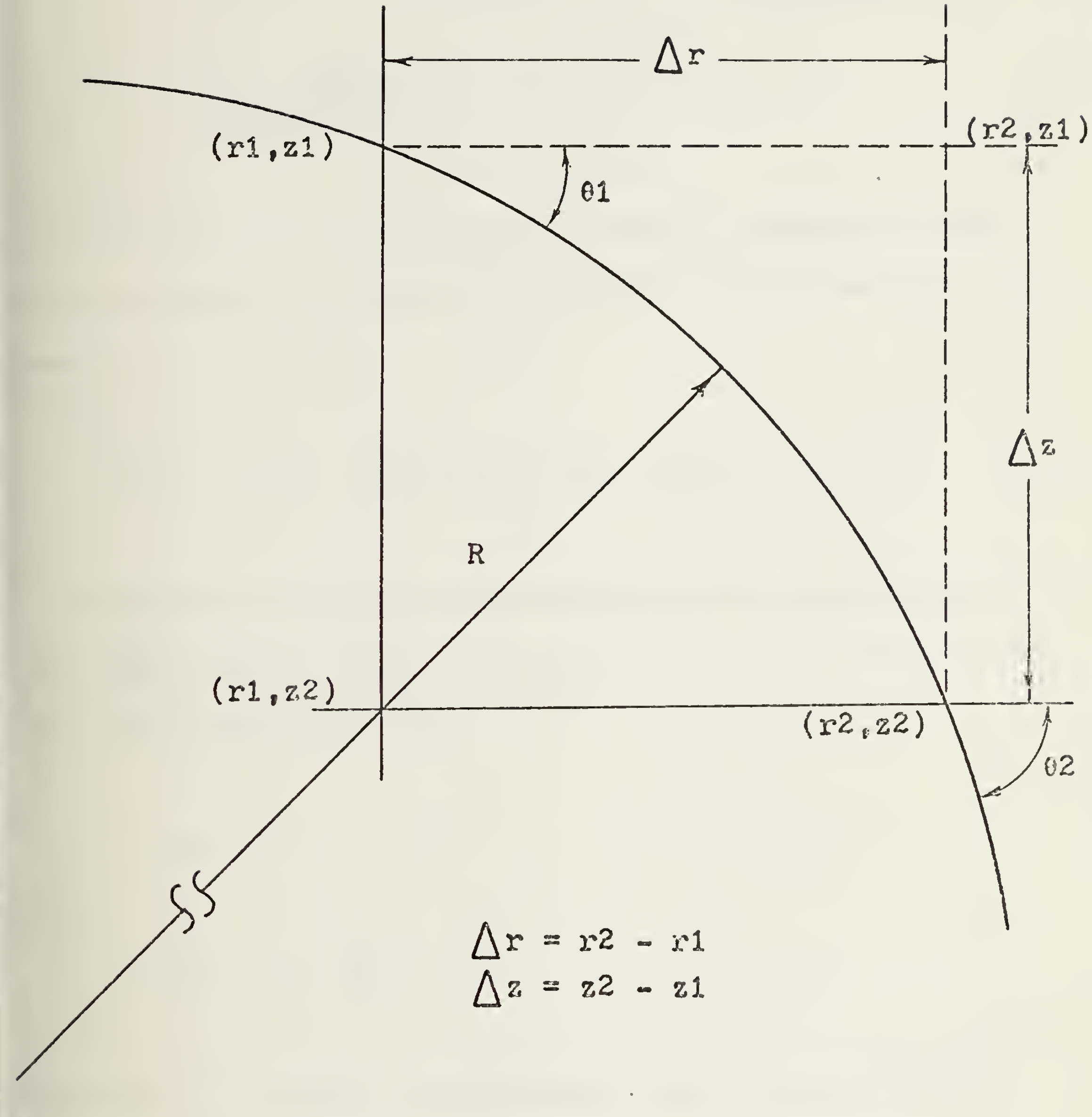


figure 6. Illustration of ray curvature within a water column.

Expanding $\Delta Z1$ as a MacLaurin series about $\Delta r = 0$ gives

$$\Delta Z2 = \tan\theta 1(\Delta r) + \frac{1}{2R(\cos\theta 1)^3}(\Delta r)^2 + \frac{\sin\theta 1}{2R^2(\cos\theta 1)^5}(\Delta r)^3$$

$$+ \frac{1 - 4(\sin\theta 1)^2}{8R^3(\cos\theta 1)^7}(\Delta r)^4 + \ldots \qquad (2)$$

Substitution of the trigonometric series representations of tan x and cos x into the first two terms of equation (2) gives

$$\Delta Z3 = \theta 1(1 + \frac{\theta 1^2}{3})(\Delta r) + \frac{(1 + 1.5\theta 1^2)}{2R}(\Delta r)^2 . \qquad (3)$$

To conserve program space and reduce the computation time, PEAPS uses a simplified form of Eq. (3). Use of the small angle approximations

$$\sin\theta = \theta$$

and

$$\cos\theta = 1 - \frac{\theta^2}{2} ,$$

where θ is in radians, yields the simple approximations

$$\Delta Z = (\theta 1)(\Delta r) + \frac{(\Delta r)^2}{R} \qquad (4)$$

and

$$\Delta\theta = \Delta r/R .$$

or Eq. (4) to accurately represent Eq. (3), restrictions ust be imposed on Δr and $\theta 1$. In order that omitting $\theta 1^2$ ntroduces no more than 10% error, $\theta 1$ must be less than .33 radians. To determine the limits on Δr, examine the ase of "worst possible" conditions:

1. A maximum gradient of 0.5 $\sec^{-1}$ and a minimum sound peed of 4700 ft/sec are assumed so that the minimum radius f curvature is 9400 ft.
2. The maximum allowable angle of depression of 0.35 adians (20°) is taken.

o ensure that no layer is missed or poorly represented in he ray trace, five depth increments are required within any ayer of depth D. Then, the first-order term in Eq. (4) ields the equation

$$\Delta r \leq \frac{D}{5\theta 1} = 0.57D \tag{5}$$

s an approximate bound on the allowed Δr within a layer f depth D.

So that the truncation of Eq. (2) to second order in Δr introduces no greater error, the third term of the equation ust be much less than the second,

$$\frac{\sin\theta 1}{2R^2(\cos\theta 1)^5}(\Delta r)^3 << \frac{1}{2R(\cos\theta 1)^3}(\Delta r)^2$$

r

$$\Delta r << \frac{R(\cos\theta 1)^2}{\sin\theta 1} \leqq 2.6R \quad .$$

If Δr is required to be at least one order of magnitude smaller than 2.6R, then

$$\Delta r \leq 0.26R \leq 2444 \text{ ft.}$$

However, since for small $\theta 1$ the third term becomes arbitrarily small, it is also necessary to require that the fourth term of Eq. (2) be much less than the second,

$$\frac{1 + 4(\sin\theta 1)^2}{8R^3(\cos\theta 1)^7} (\Delta r)^4 << \frac{1}{2R(\cos\theta 1)^3} (\Delta r)^2 ,$$

or

$$\Delta r << (2R)(\cos\theta 1)^2 [1 + 4(\sin\theta 1)^2]^{\frac{1}{2}} = 2.1R .$$

If Δr is to be at least one order of magnitude less than 2.1R, then

$$\Delta r \leq 0.21R \leq 2012 \text{ ft.}$$

To estimate the error in calculating ΔZ from Eq. (4), subtract Eq. (4) from Eq. (3):

$$\Delta Z3 - \Delta Z = \frac{\theta 1^3}{3} (\Delta r) + \frac{3\theta 1^2}{4R} (\Delta r)^2 \qquad (6)$$

The fractional error is given by:

$$\frac{\Delta Z3 - \Delta Z}{\Delta Z3} = \frac{0.014 + (9.56 \times 10^{-6})(\Delta r)}{0.36 + (1.16 \times 10^{-4})(\Delta r)}$$

Away from a turning point, for large angles where the difference defined by Eq. (6) is large, the error is approximately 4% for small Δr and approximately 8% for large Δr. If the error is required to be no greater than 5%, then Δr must be no greater than about 1000 feet (near a turning point, $\Delta Z3 - \Delta Z$ approaches zero very rapidly, so that errors in depth are negligible for small angles of elevation or depression).

Based on these error requirements, the simple equation

$$\Delta r = 5(D)^{\frac{1}{2}}$$

was used for Δr and D in feet. For the ranges of D employed in PEAPS the restrictions on Δr set forth above are not seriously violated (Table II).

E. OUTPUT

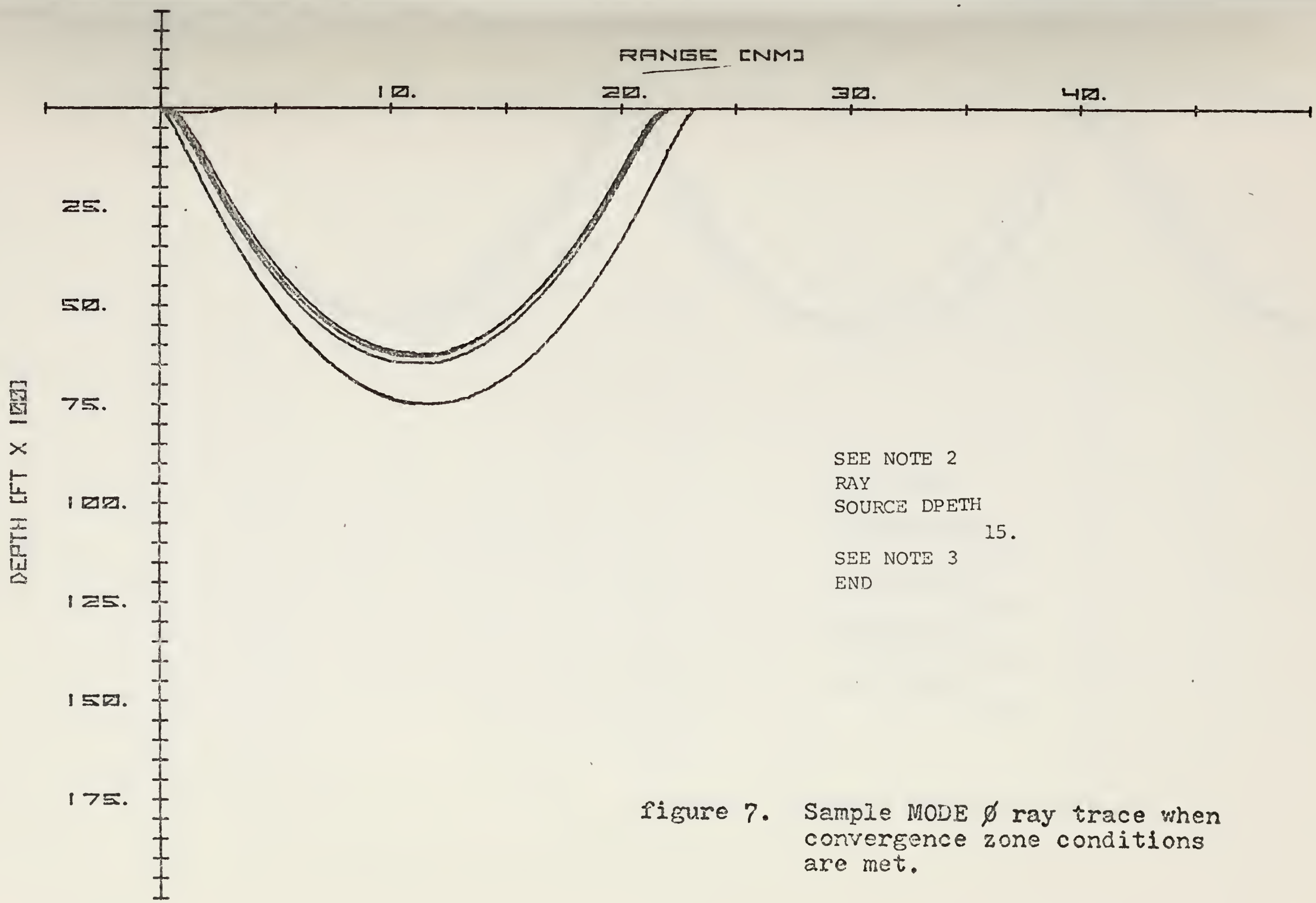
If convergence zone (CZ) conditions are not present, "NO CZ" appears on the printer. In all cases "SEE NOTE 3" and "END" appear, indicating the end of the SSP/Ray Trace programming sequence, and referring the user to Operator Note 3 (Appendix C).

TABLE II

Comparison of PEAPS and theoretical range increment values

D	$\Delta r = \min(0.57D, 1000)$	$\Delta r = 5[D]^{\frac{1}{2}}$
50	28.5	35.3
100	57.0	50.0
200	114.0	70.7
400	228.0	100.0
800	456.0	141.4
1600	912.0	200.0
3200	1000.0	282.8
6400	1000.0	400.0

Graphic outputs depend upon the Mode number chosen. Figure 7 is an illustration of a Mode 0 run when CZ conditions are met. Figure 8 shows a Mode 2 run. These pictorial outputs may serve as training aids in either a classroom or a shipboard environment to demonstrate the dependence of ray paths on the vertical sound speed structure. Mode 1 has no graphic ray trace output.



SEE NOTE 2
RAY
SOURCE DPETH
15.
SEE NOTE 3
END

figure 7. Sample MODE 0 ray trace when convergence zone conditions are met.

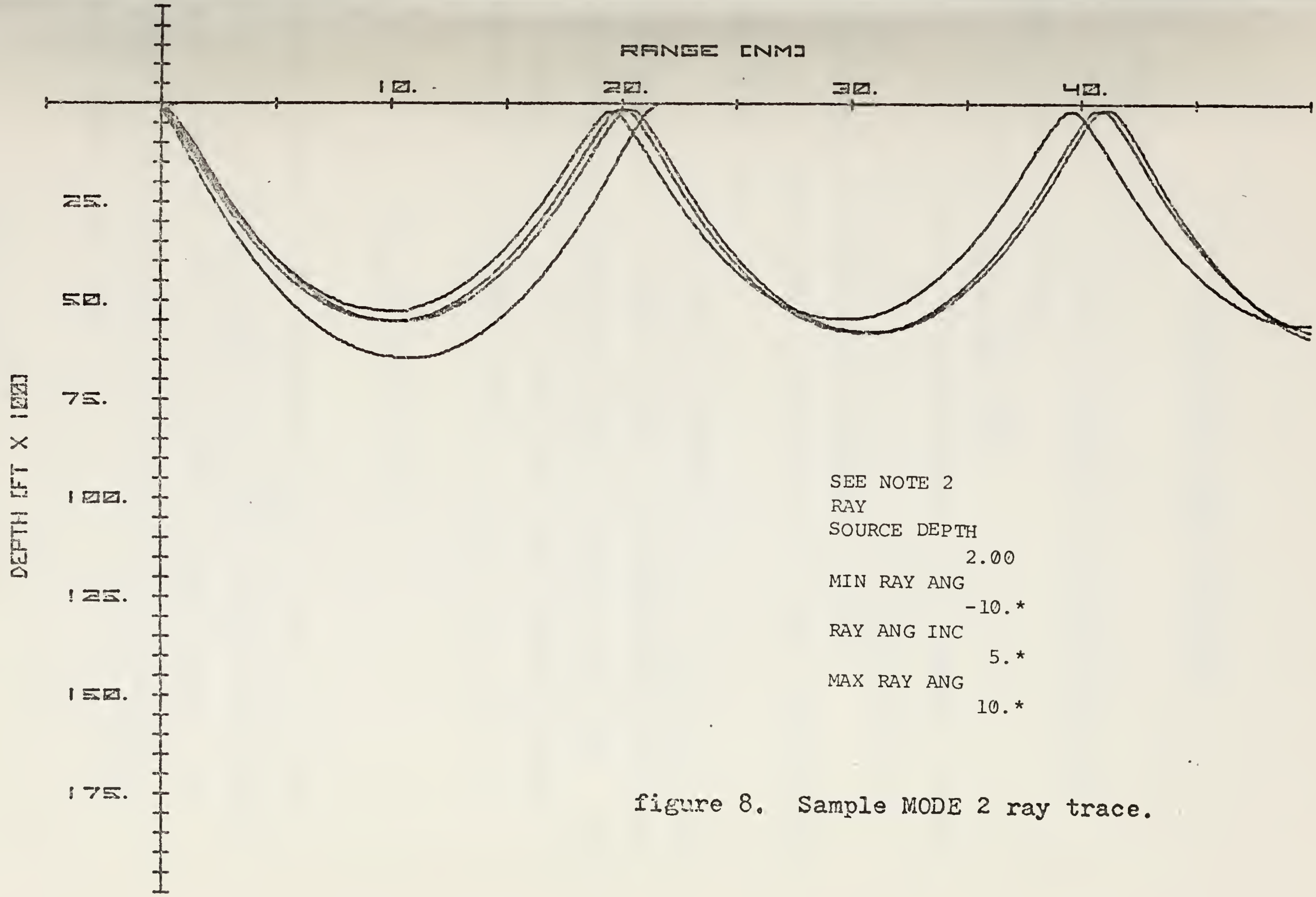


figure 8. Sample MODE 2 ray trace.

IV. TRANSMISSION LOSS GENERATOR

A. PATH SELECTION

Transmission loss is computed for paths which meet the following criteria:

1. Surface Duct Path (SDP)

a. The sound speed profile (SSP) contains a sonic layer. A sonic layer is defined as the layer above the first negative sound-speed gradient (Fig. 9).

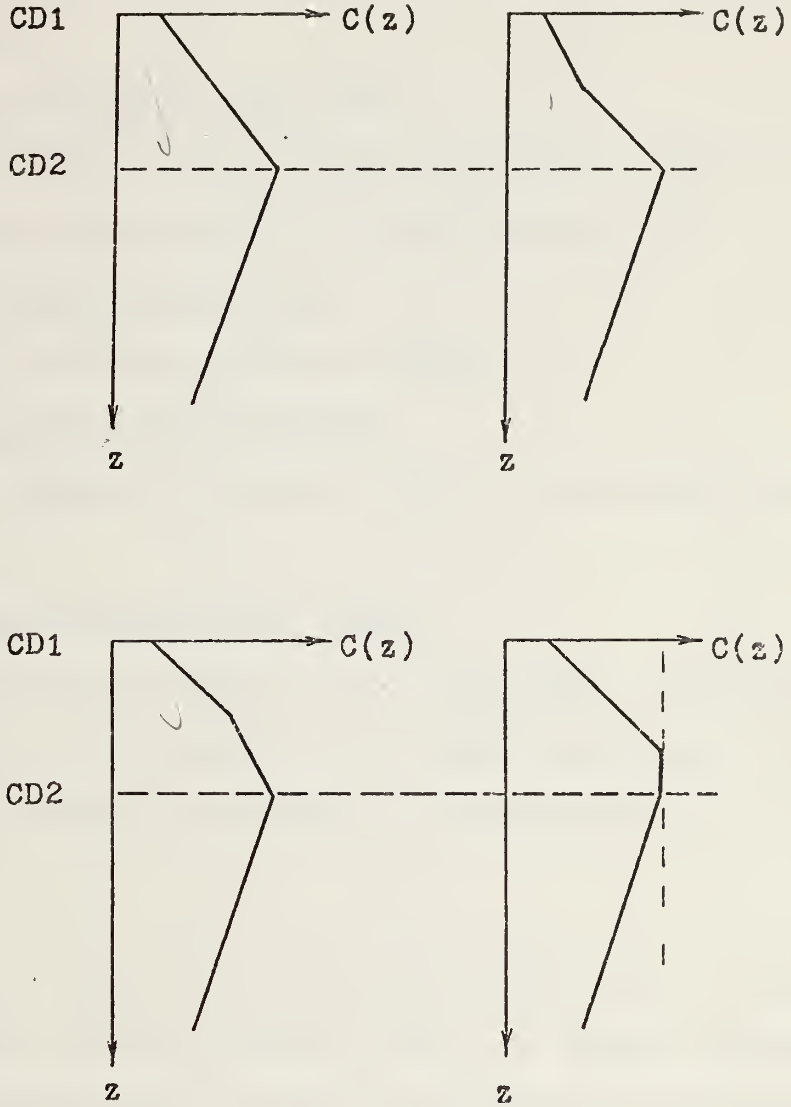
b. The source and receiver are both located within the sonic layer.

c. Sound remains trapped in the sonic layer. This trapping fails to occur at very low frequencies, where the wavelength has become too large to "fit" in the duct. Using a sound speed of 5170 ft/sec and a sound speed gradient of 0.017 $\sec^{-1}$ in the sonic layer, we have from Urick [2]

$$H_{min} = 36.64 \lambda^{0.667},$$

for the minimum duct thickness (H_{min}) in feet which will trap sound with wavelength λ in feet. Urick states that this expression does not represent a sharp cutoff. To reduce programming steps for the calculator, the H_{min} equation was simplified to

$$H_{min} = 32 \lambda^{0.7} .$$



CD1 = Surface
CD2 = Sonic Layer Depth (SLD)

Figure 9. Illustrations of Sonic Layer Depths (SLD).

Table III compares the frequencies and corresponding minimum duct thickness as determined by PEAPS, Urick, and ASRAP III correction tables.

2. Reliable Acoustic Path (RAP)

RAP conditions always exist except when the source and receiver are both located in a sonic layer.

3. Bottom Bounce Path (BBP)

Bottom Bounce Path always exists.

4. Convergence Zone Path (CZP)

CZP is computed if an SSP with a sound speed excess is present (Fig. 4).

5. Deep Sound Channel Path (DSCP)

The Deep Sound Channel Path exists when the source and receiver are both located in the deep sound channel and the sound speed profile can support CZ propagation.

B. INPUTS

The operator loads the TL/PD program and enters (from the TL/PD portion of the worksheet) (Fig. 5) source frequency (Hz), Figure of Merit (dB), System Sigma (dB), wave height (ft), and MGS bottom type. Although the figure of merit and system sigma are used only in the PD generator, they are entered at this time to simplify operator procedures.

The transmission loss sub-program uses the following values from the ray trace generator: a CZ indicator, the maximum and minimum CZ ranges where CZ conditions exist, the minimum bottom bounce angle, and the depths and speeds

TABLE III

Comparison of minimum duct thickness

Frequency (Hz)	(ft)	Minimum Duct Thickness - H_{min} (ft)		
		PEAPS	Urick	ASRAPS III
53	97.5	789.7	776.2	750
104	49.7	492.7	495.3	475
208	24.9	303.7	312.4	300
588	8.8	146.6	156.2	150
1080	4.8	95.9	104.3	100
3055	1.7	46.4	52.2	50

of sound at the critical points of the sound speed profile (sonic layer, deep sound channel axis, etc.).

C. TRANSMISSION LOSS MODELS

The program looks at each path selected and determines transmission losses according to certain simple models. Names used in this section are those used in the FORTRAN version of the PEAPS program (Appendix D).

1. Surface Duct Path (SDP)

Figure 10 illustrates SDP.

$$TL_{SDP} = 20\log(R) + AR + DFL*R \quad \text{for } R < RT \text{ , } R < RS$$

$$TL_{SDP} = 10\log(R) + AR + DFL*R + 10\log(RT)$$
$$\text{for } RT < R < RS$$

$$TL_{SDP} = 10 \log(R) + AR + DFL*R + 10\log(RT) + SSL*R$$
$$\text{for } R > RS \text{ , } R > RT$$

$$TL_{SDP} = 20\log(R) + AR + DFL*R + SSL*R \quad \text{for } RS < R < RT$$

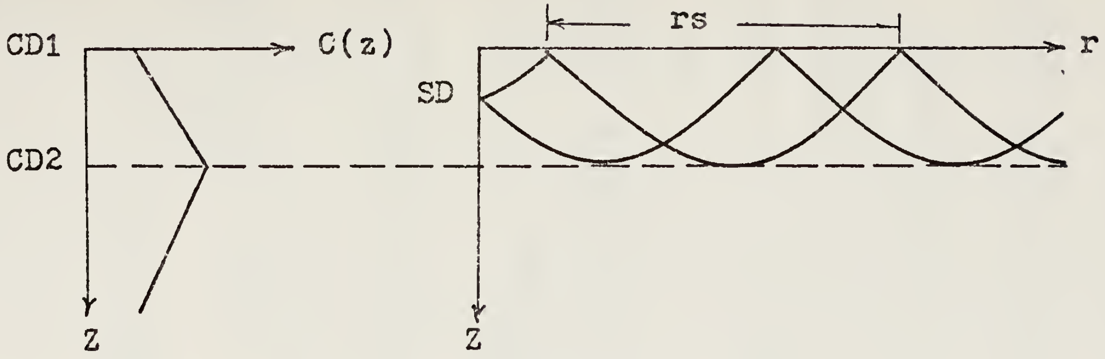
where R = the horizontal distance from the source to the receiver in yards

A = the absorption coefficient [3],

$$= \left[\frac{0.1F^2}{1+F^2} + \frac{40F^2}{4100+F^2}\right] * 10^{-3} \quad \text{(dB/yd)},$$

F = frequency in kilohertz (KHz);

figure 10. Surface Duct Path



CD1 = Surface
CD2 = SLD
SD = Source Depth
rs = Surface Duct Skip Distance

DFL = diffractive leakage out of the duct based on Normal Mode Theory [4 and 5], given by

$$744F^{-1.66}G^{-0.33}(CD2)^{-3} * 10^{-3} \text{ (dB/yd), and}$$

G = the below-layer gradient = $\frac{CS3 - CS2}{CD3 - CD2}$;

CD2 = the sonic layer depth (ft);

CD3 = the depth below CD2 at which the next positive gradient begins or the bottom depth (ft);

CS2, CS3 = the sound speeds (ft/sec) which correspond to CD2 and CD3, respectively

RT = the transition range (the range at which the duct is considered full and cylindrical spreading begins) in yards [2] = $\frac{CD2}{6\arccos(SV/CS2)}$

SV = the speed of sound at the source (ft/sec).

RS = the skip distance (the range between consecutive surface reflections of the deepest trapped ray) in yards [2] = $\frac{2\arccos(CS1/CS2)}{3(RADINV)}$ (yd)

RADINV = the inverse of the radius of curvature of a ray within the surface duct = GD/SD.

SD = the depth of the source of sound (ft).

GD = the effective gradient in the sonic layer = $\frac{CS2 - CS1}{CD2 - CD1}$

SSL = sea surface loss = $\frac{0.8B^{0.71}}{RS}$ (dB/yd)

B = F*H

H = wave height (ft).

The expression for SSL was developed from a power regression analysis of data presented in Reference 6, and is valid for values of B between 0 and 30.

2. Reliable Acoustic Path (RAP)

From Fig. 11,

$$TL_{RAP} = 20\log(K) + A*K ,$$

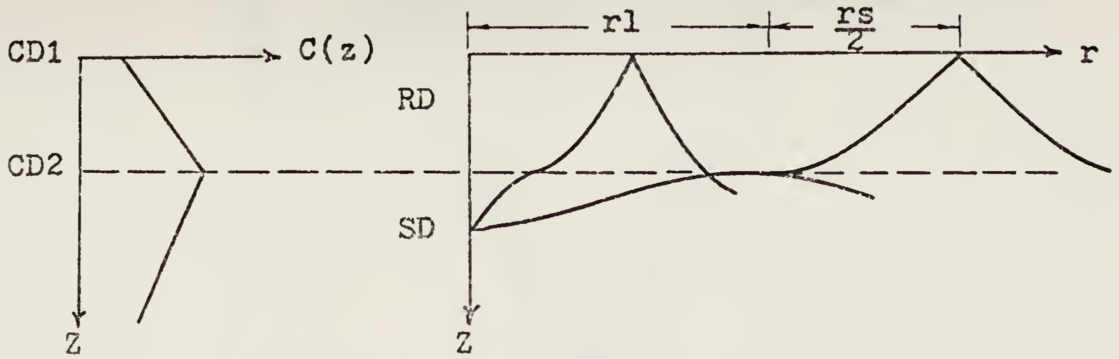
where K is the slant range from the source below the layer to the surface at range R, in yards.

The maximum RAP range = RL + RS/2, where RL is the cutoff range, defined as the horizontal distance from the source to the point at which a ray just grazes the bottom of the sonic layer (or surface if no sonic layer exists), and RS is the skip distance (described previously in the surface duct model).

3. Bottom Bounce Path (BBP)

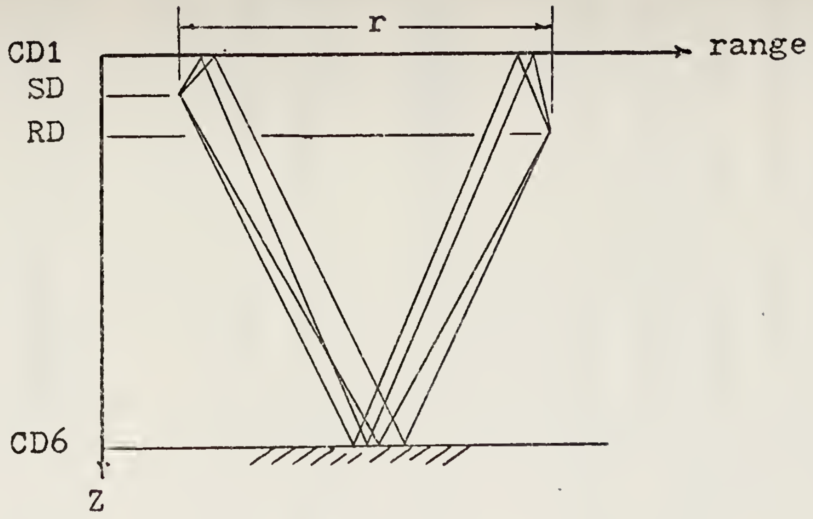
Four separate bottom-bounce paths are possible between the source and receiver: two with one surface reflection, one with two surface reflections, and one with no surface reflections (Fig. 12). Incoherent superposition of these rays at the receiver results in a 6 dB reduction in the transmission loss. For emission angles greater than about 15°, the radius of curvature of a ray is usually large enough to assume straight-line propagation of the rays from the source to the bottom and back to the surface. A ray from the source will strike the bottom at an angle of incidence estimated by

figure 11. Reliable Acoustic Path



CD1 = Surface
CD2 = SLD
RD = Receiver Depth
SD = Source Depth
rs = Surface Duct Skip Distance
rl = The horizontal distance a ray travels to reach CD2 from SD.

figure 12. Bottom Bounce Paths



CD1 = Surface
CD6 = Bottom Depth
SD = Source Depth
RD = Receiver Depth

$$THBL = \tan^{-1}\left[\frac{CD6 - SD}{XB}\right]$$

where

$$XB = \frac{R}{N}\,\frac{(CD6 - SD)}{(2CD6 - SD)} \text{ (yds)}$$

is the horizontal distance between the source and the range of the first bottom bounce, CD6 is the bottom depth (ft), and N is the number of bottom reflections.

The distance traveled by the four rays which strike the bottom once can all be approximated by

$$\frac{R}{\cos(THBL)} \text{ (yds)}$$

for reasonably small source and receiver depths or large range. Therefore, an approximate transmission loss can be written as

$$TL_{BB} = 20\log\left[\frac{R}{\cos(THBL)}\right] + \frac{A*R}{\cos(THBL)} + N*BL - 6$$

where the subtraction of 6 takes into account the 6 dB gain caused by multiple bottom bounce paths, and BL is a bottom loss term which was determined through regression analysis of bottom loss data presented in Reference 7. Specific values for BL are determined by a sorting routine which uses the input frequency and bottom type. THBL is the angle at which the ray strikes the bottom.

4. Convergence Zone Path (CZP)

See Fig. 4.

$$TL_{CZ} = 20\log(R) + A*R$$

when R is outside the CZ annulus and

$$TL_{CZ} = 20\log(R) + A*R - GCZ$$

when R is bounded by CZSTRT and CZSTOP. The CZ annulus is defined as the width of the zone, CZSTOP - CZSTRT, in yards. GCZ is the reduction in transmission loss caused by the increase in sound pressure level (SPL) which results from ray focusing within the ray family forming the CZ annulus.

$$GCZ = \frac{RP}{GB} \exp(-RP^2/2GB)$$

$$RP = \frac{RANGE}{0.18X} (GB)^{\frac{1}{2}}$$

$$GB = \frac{0.36}{GCZMAX^2} \ (yd^{-2})$$

RANGE = R - CZMIN (yds)

X = CZ annular width (yds)

$GCZMAX = 15.4545 - 4.545 * 10^{-4}X$ (yds)

The equations for GCZ and GCZMAX are empirical and were derived from analysis of numerous transmission loss curves obtained as output from the FACT model [5]. The analysis

established that the gain distribution within a convergence zone closely resembled a Rayleigh distribution and that the gain tended to a maximum at approximately 18% of the annular width. Thus, GCZ was modelled as a Rayleigh distribution with the peak occurring at a distance from CZSTRT equal to 18% of the annular width (Fig. 13).

5. Deep Sound Channel Path (DSCP)

See Fig. 14.

$$TL_{DSCP} = 10\log(R) + A*R + 10\log(RTP)$$

where RTP is the deep sound channel transition range,

$$RTP = \frac{CZMIN}{8} \left(\frac{D}{Z}\right)^{\frac{1}{2}}$$

D = CD3 - CD2 in feet,

CD3 = depth of the sound channel axis (ft),

Z = SD - CD2 (ft),

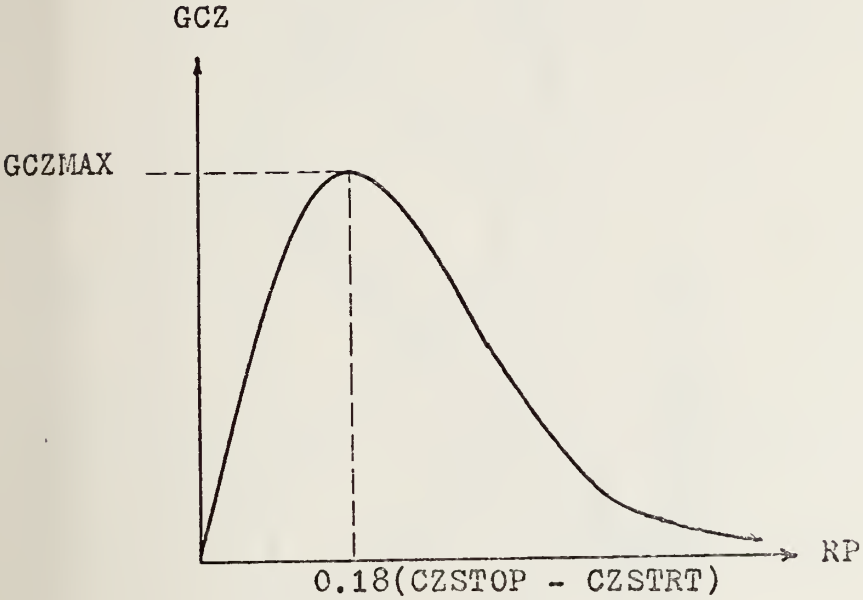
CZMIN is in yards.

The transmission loss term is valid only for $R > RTP$, although it is used for all R when this path is present.

D. COMBINED TRANSMISSION LOSS

Since transmission loss caused by bottom bounce is always present, the total transmission loss (STL) is initialized with TL_{BB} after each increment of range. Transmission loss for subsequent propagation paths meeting their respective

figure 13. Convergence Zone Gain Model



$$GCZMAX = 15.5 - (0.00045(CZSTOP - CZSTRT))$$

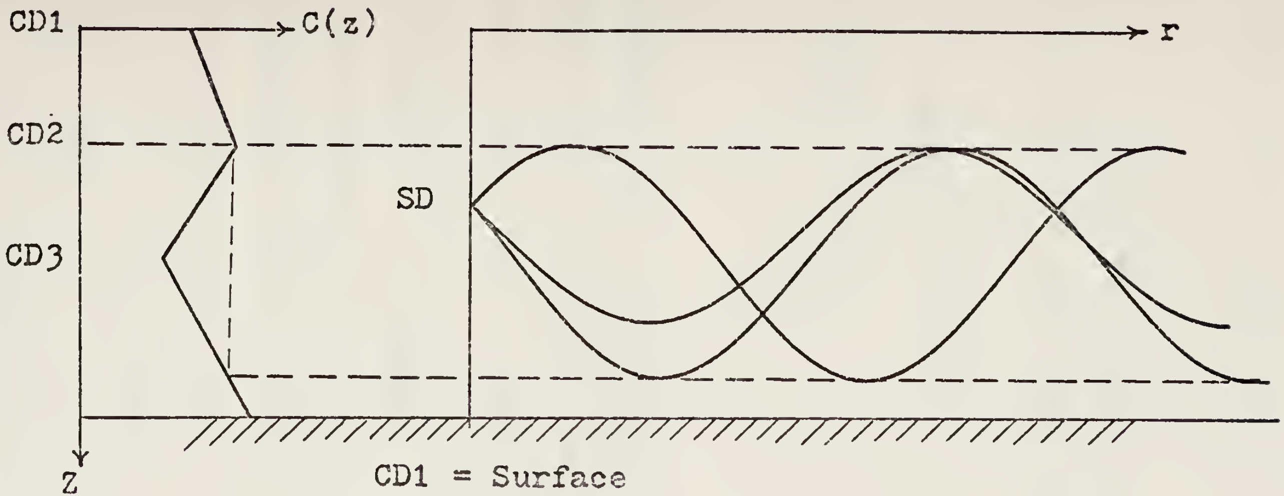
$$GB = 0.36 / GCZMAX^2$$

$$RANGE = r - CZSTRT$$

$$RP = \frac{(RANGE \times \sqrt{GB})}{(0.18(CZSTOP - CZSTRT))}$$

$$GCZ = \left(\frac{RP}{GB}\right) \exp\left(\frac{-RP^2}{2GB}\right)$$

figure 14. Deep Sound Channel Path



CD1 = Surface
CD2 = SLD
CD3 = Channel Axis Depth
SD = Source Depth

existence criteria are computed for the same range and combined with STL as follows: If ⊕ signifies the combining of decibels (dB) for independent (phase incoherent) signals, then

$$STL \oplus TL(i) = STL - A$$

where TL(i) is the transmission loss for the specific propagation path (CZ, SDP, DSC, RAP, as they exist).

$$A = 10\log(1 + 10^{-0.1J})$$

$$J = \left(\left|STL - TL(i)\right|\right).$$

E. OUTPUT

The program plots the combined transmission loss (STL) in dB versus range in nautical miles (NM), with a reference line for the input figure of merit (Fig. 15).

F. SHORTCOMINGS OF THE MODELS

Since the models were developed for use in a relatively small programmable desk-top calculator, limitations in the available storage and the number of program steps have resulted in certain shortcomings:

1. Phase coherence is neglected.
2. Sea surface scattering is not taken into account in calculating TL for the convergence zone model.
3. If the source is in the sonic layer and the duct thickness is less than H_{min}, propagation in the layer is neglected.

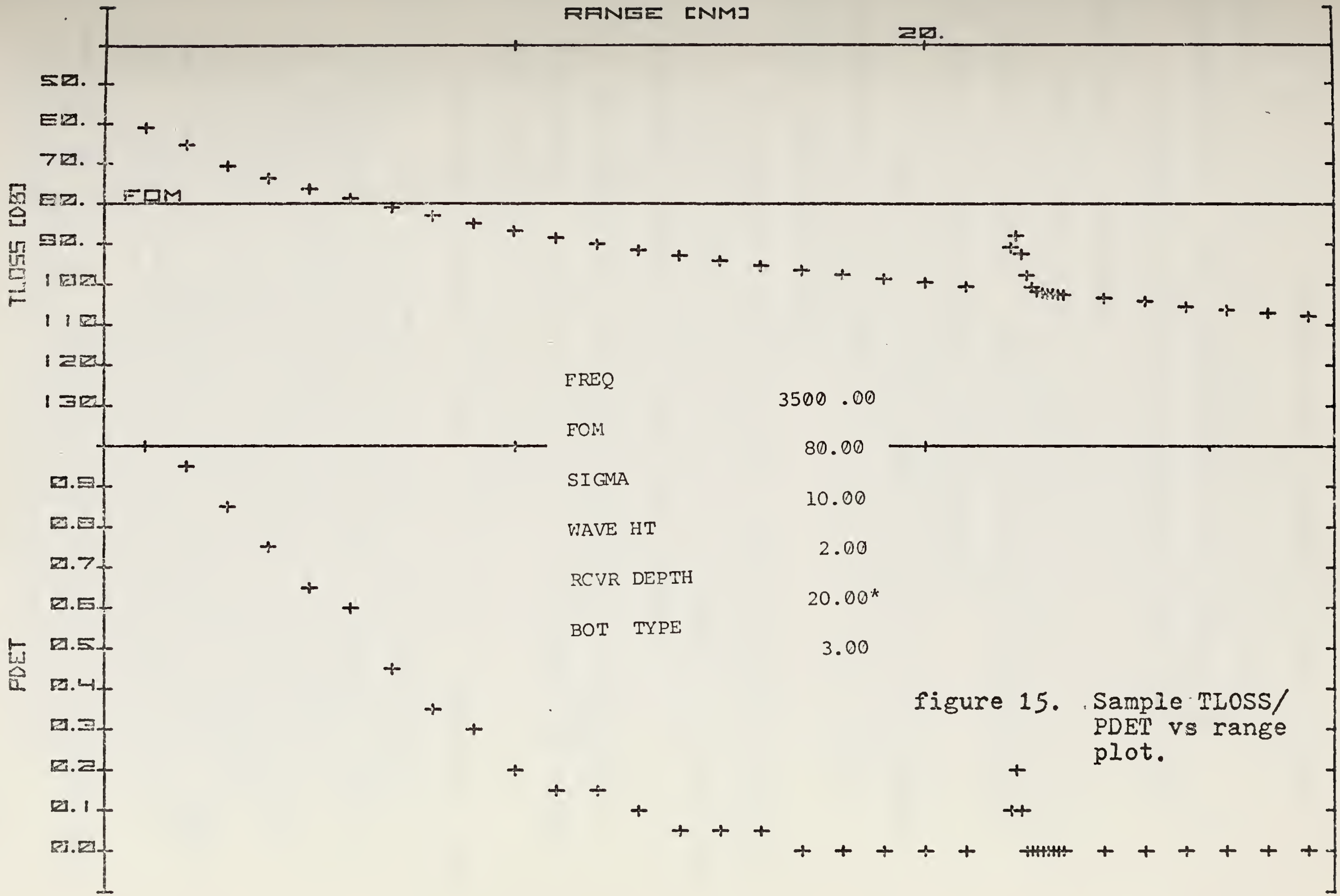


figure 15. Sample TLOSS/PDET vs range plot.

4. The use of straight-line propagation will induce some error in the angles computed for bottom bounce parameters and in the transmission loss computation.

5. Convergence zones are considered when any sound speed excess is present.

6. The convergence zone gain term, GCZ, is found from an empirical formula: there is no physical justification for the use of the Rayleigh distribution.

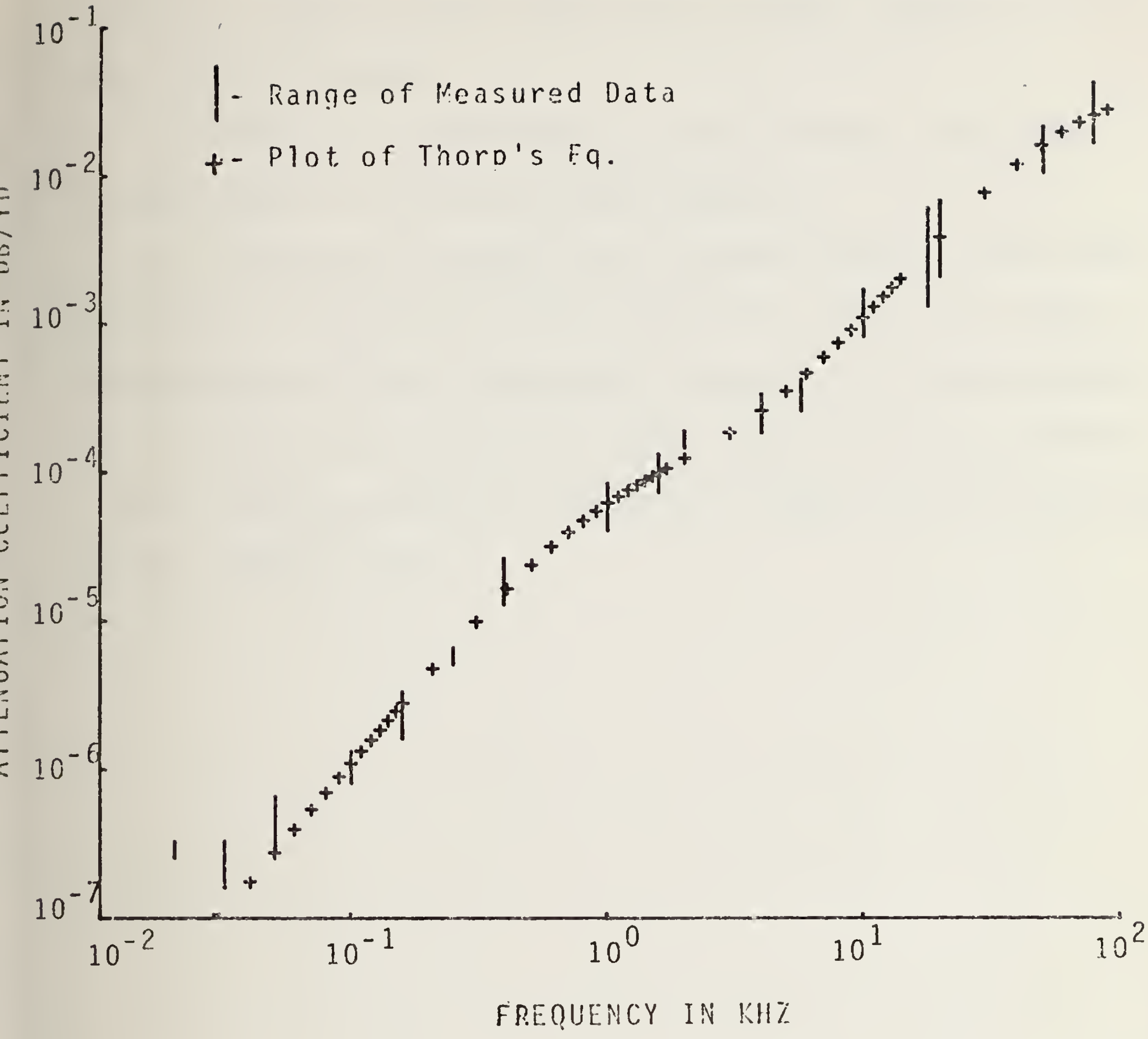
7. The model for the deep sound-channel overestimates transmission loss for ranges less than the (deep sound-channel) transition range.

8. For reliable acoustic path, steep-gradient curvature is not considered; transmission loss is computed for straight line distances between the source and receiver.

9. The absorption loss term uses Thorp's formula for all frequencies. As shown in Fig. 16, the formula is good for frequencies greater than 20 Hertz.

10. The diffraction loss term, DFL, is the same term used in FACT [5]. The following is a quote from Reference 5:

> A preliminary analysis of this model (Labianca, 1972) has shown that the leakage term does not correspond to the mechanism which dominates duct leakage and, in particular, has the wrong dependence on the below-layer (thermocline) gradient. An intensive investigation of all available surface duct models has been completed recently by NUC (Naval Undersea Center) for LRAPP (Long Range Acoustic Propagation Project) (Morris, 1974). This study compared several models with each other and the SUDS (Surface Duct Sonar) transmission loss data (Cummins, 1972). Since none of the candidate models emerged as clearly superior, AESD (Acoustic Environmental Support Detachment) is currently studying possible modifications to the surface-duct equations. [5]



Measured data taken from the North Atlantic (Thorp and Bernier, 1959 and 1962; Sussman, MacDonald, and Kânabis, 1963), Mediterranean (Lallement and Waterman, 1963; Leroy, 1964), and Northern Pacific (Greer and Polam, 1954; Sheehy and Halley, 1957) [3].

Thorp's Eq.: $$\text{Attenuation} = \left[\frac{0.1F^2}{1+40F^2} + \frac{40F^2}{4100+F^2}\right] \times 10^{-3}\ \text{dB/yd}$$

Figure 16

11. Convergence zone parameters are determined at the surface. Errors exist when source and/or receiver are at appreciable depths.

12. When CZ conditions are not present, the model assumes there is no deep sound channel.

13. Leakage of sound into a shadow zone is not considered. If there are no CZ conditions, then the only illumination of the shadow zone comes from bottom bounce. If CZ conditions exist the shadow zone is illuminated by a path having spherical spreading in addition to the bottom bounce illumination.

V. PROBABILITY OF DETECTION (PD) GENERATOR

A. INPUTS

The sub-program for probability of detection contains values from the cumulative distribution function (CDF) for a standardized normal random variable, CDF = F(x). Values of x corresponding to F(x) = 0.5, 0.55, ..., 0.95 are stored.

The figure of merit (FOM) and system sigma are entered by the operator as part of the transmission loss initialization procedure. System sigma is defined as the square root of the sum of the variances of the individual terms in the passive sonar equation:

$$\text{System sigma} = (\sigma_{SL}^2 + \sigma_{NL}^2 + \sigma_{DI}^2 + \sigma_{DT}^2 + \sigma_{TL}^2)^{\frac{1}{2}}$$

where σ is the deviation.

Rule-of-thumb values for system sigma are included in Operator Note 3 (Appendix C) for those cases in which variances of the individual term are unknown.

B. MODEL

The detection variable X is defined as the ratio of the signal excess,

$$SE \equiv FOM - TL \quad ,$$

to the system sigma:

$$X \equiv \frac{SE}{\text{System Sigma}} \quad .$$

The computed X is compared to the stored values of x to determine probability of detection at which PD = F(X).

C. OUTPUT

The program plots a probability of detection (PD) versus range directly below the TL versus range plot (Fig. 15). The PD routine computes PD in increments of 0.05 so that a smooth curve does not result.

VI. CONCLUDING REMARKS

Advanced development of an on-board environmental prediction system resulted in the Integrated Command ASW Prediction System (ICAPS) computer program. ICAPS uses the FACT transmission loss program so that it requires computer resources comparable to those available on aircraft carriers. This development effort is continuing with emphasis upon the development of a smaller version of FACT. A viable alternative would be an augmented version of PEAPS.

Fleet introduction of an environmental prediction system need not be delayed until a foolproof system is available. With PEAPS available, even in its present limited form, operational evaluation of an interim system with some known shortcomings is entirely feasible. A continuing dialogue, carried on between the developmental agency and the operating forces, would facilitate implementation of system improvements based upon fleet experience.

The operating forces have never had a tactical environmental prediction capability available at the individual platform level. PEAPS provides an inexpensive way to evaluate the operational utility of such a system.

APPENDIX A

PEAPS HARDWARE DESCRIPTION

For this program the Hewlett-Packard Model 9810A calculator must be configured with the following options:

Option 001: Total of 111 data-storage registers;

Option 003: Total of 2036 program steps;

Option 004: Printer.

Read-only-memory units (ROM's) required are:

Mathematics ROM - hp - 11210A

Printer Alpha ROM - hp - 11211A

Plotter ROM - hp - 11215A.

The Hewlett-Packard Model 9862A Plotter is required to produce the graphical output.

APPENDIX B

The following pages are samples of the Operator Worksheet developed for use with the PEAPS program.

PEAPS OPERATOR WORKSHEET

(See PEAPS Operator Note Sheets)

BT Information DTG: ________________ Z ______

Location: ________________ N/S ___, ____________________ E/W ______

1. Turn the calculator and plotter on. "LOAD" the SSP/Ray trace program cards. Put the plotting paper on the plotter and set the "GRAPH LIMITS" of the plotter.

2. Press "STOP, END, CONTINUE" (this sequence is used when a new SSP is to be generated.

Note 1: If you enter an erroneous value:

  a. If you have not pressed "CONTINUE", press "CLR X", then enter the correct value.

  b. If you have pressed "CONTINUE", you must re-enter all the points again; press "GO TO, LABEL, A", then continue with Step 3 below.

3. Press "CONTINUE".

4. SSP inputs: ENTER number of BT points (15 maximum) _____ Press "CONTINUE" after each value is entered to advance the program

Point	Input Depth (ft)	Input Temp (°F)	Input Salinity (ppt)	Output Speed of Sound (ft/sec)
1	0.0			
2				
⋮	⋮	⋮	⋮	⋮
10				
	⋮	⋮	⋮	⋮
15				

Note 2: Change the plotting paper on the plotter. Enter the ray trace program MODE indicator.

MODE: _____
0 = Automatic compute and plot
1 = Automatic compute, no plot
2 = Manual inputs for plotting, Automatic compute.

If a ray trace input error is made, press "GOTO, LABEL, B, CONTINUE", then input the MODEL indicator and ray trace data again. (This sequence is used to generate a new trace using the old SSP data)

Press "CONTINUE"

4. Ray trace inputs:
Press "CONTINUE" after each input to advance the program.

Source Depth: ___________(ft)

If Mode 2 is used:

Minimum Ray Angle x 2: __________(degrees)

Angle Increment x 2: __________(degrees)

Maximum Ray Angle x 2: __________(degrees)

Note 3: If, while in Mode 0 and after the bottom limiting ray has been drawn, a channelled ray is drawn to the plot's range limit; see Operator Note sheet section Note 2E.
Change the plotting paper on the plotter. Press "STOP, END". LOAD the TLOSS/PD program cards. Press "STOP,END". (The "STOP, END" sequence is used when a TLOSS/PD input error is made, or a new TLOSS/PD plot is to be generated based on the old SSP/Ray trace data.)

5. TLOSS/PD inputs:
Press "CONTINUE" after each input to advance the program.

Press "CONTINUE"

Source Frequency: ____________(Hz)

Figure of Merit (FOM):________(dB)

System Sigma: ________(use 10 if unknown)

Wave Height: 0 1 2 3 4 5 6 7 8 9 10 11 12 (ft)

Receiver Depth: ________(ft)

Bottom Type: 1 2 3 4 5 6 7 8 9

Note 4: If a new ray trace is to be generated using the old SVP data after the TLOSS/PD program has been run, Press "STOP, END". LOAD the SVP/Ray trace program cards.

Press "GOTO, LABEL, B, CONTINUE", then see Note 2 above.

APPENDIX C

PEAPS OPERATOR NOTE SHEETS FOR THE HP9810A

SSP/RAY TRACE PROGRAM

The SSP/RAY Trace program is recorded on two short magnetic cards, each card having two sides. The program is inserted into the calculator as follows (it is assumed the calculator is turned on and paper has been placed on the plotter).

1. Press: END, LOAD.
2. Insert the cards starting with side 1 sequentially through side 4.
3. Press: END, CONTINUE.

After the SSP axes have been drawn the printer will indicate "SEE NOTE 1", referring the operator ot Note 1.

Note 1

A. The sound speed profile (SSP) generator will accept up to fifteen (15) points. These points are entered from the PEAPS Computer Operation Worksheet starting with the first point being the surface (depth = 0) temperature and salinity. The data are entered as follows:

1. Press: CONTINUE

The printer will request "NO. PTS". Enter the number of BT points to be entered as indicated on the worksheet.

2. Press: CONTINUE.

The printer will request DEPTH. Enter the depth in feet of the point for which data are being entered (enter 0 for point 1).

3. Press: CONTINUE.

The printer will print the depth entered and request TEMP. Enter the temperature in °F for the point of interest.

4. Press: CONTINUE.

The printer will print the temperature entered and request SALIN. Enter the salinity in parts per thousand for the point of interest.

5. Press: CONTINUE.

The printer will indicate the salinity entered and the speed of sound in feet per second corresponding to the depth, temperature, and salinity values immediately preceding the sound speed value. The plotter will plot the speed of sound indicated on the printer at the corresponding depth. If the data entered are from a point less than the total number of points to be entered, the printer will indicate DEPTH. Enter the depth of the next point of interest and continue from step 3 above. If the date entered is for the last point, the program will discontinue plotting and the printer will indicate "SEE NOTE 2". This refers to Operator Note 2 below.

B. If the BT trace does not reach the bottom:

1. Use at least two points from historical data and enter these as the last two points. The more points entered, the more accurate the plot if the bottom is considerably deeper than the BT trace depth. See Section G below for merging data.

2. If historical data are not available, enter the last BT temperature as the bottom temperature, the bottom depth as measured or approximated, and 35 ppt as salinity.

C. If salinity values are not available from measurements or historical data, enter 35 ppt.

D. If you enter an erroneous value:

1. If you have not pressed CONTINUE, press "CLR X", then enter the correct value.

2. If you have pressed CONTINUE, you must reenter all the points again; press "GO TO, LABEL, A", then continue from step 2 in Section A above.

E. If you have finished with one sound speed profile and want to enter a new one, press "END", then go to step 1 in Section A above.

F. Pressing "CONTINUE" after each input advances the program and enters the input point into storage.

G. If the in-situ and historical data do not match closely together, merging becomes necessary. There is no single correct method for merging historical and in-situ data. Suggested procedures are to fare (draw a smooth curve) the two profiles together, to extrapolate the in-situ trace

down to the historical data, or to extend the profiles in the area of interest until they meet. Fig. 17a shows a plot of in-situ SSP and historical data on the same axis. It is suggested that this be done for all SSP plots if historical data are available. A trace of the historical data need not start at the surface. A depth 500 feet above the last BT depth should suffice. Figures 17b and 17c show examples of extending the two traces to achieve a merge. In any event, a smooth blending of the traces should be attempted. In some instances it may be necessary to try more than one technique in order to achieve a reasonably correct facsimile of the sound speed structure.

Note 2

This Note deals with procedures for the ray trace generator.

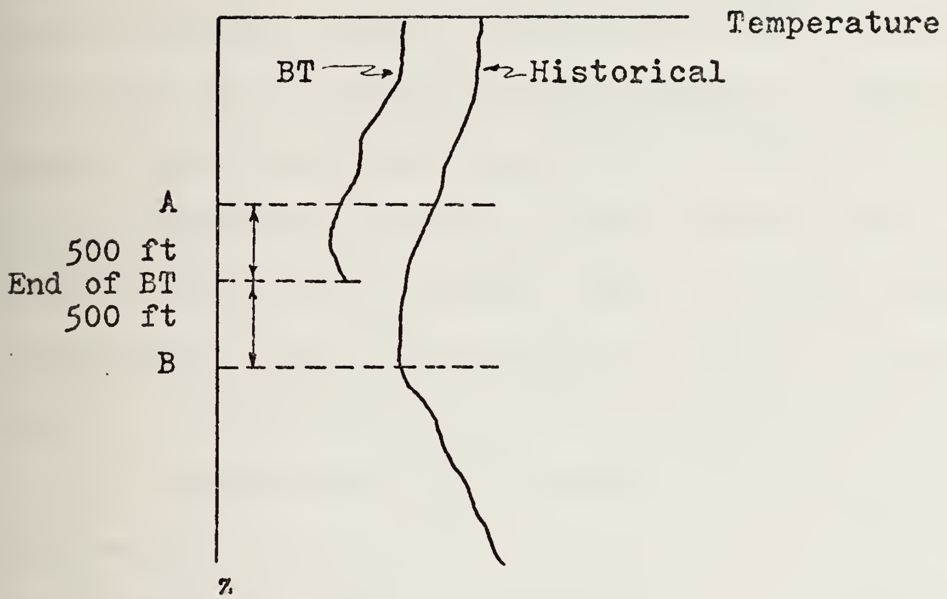
A. Change the plotting paper.

B. Enter the ray trace program Mode indicator (0, 1, or 2).

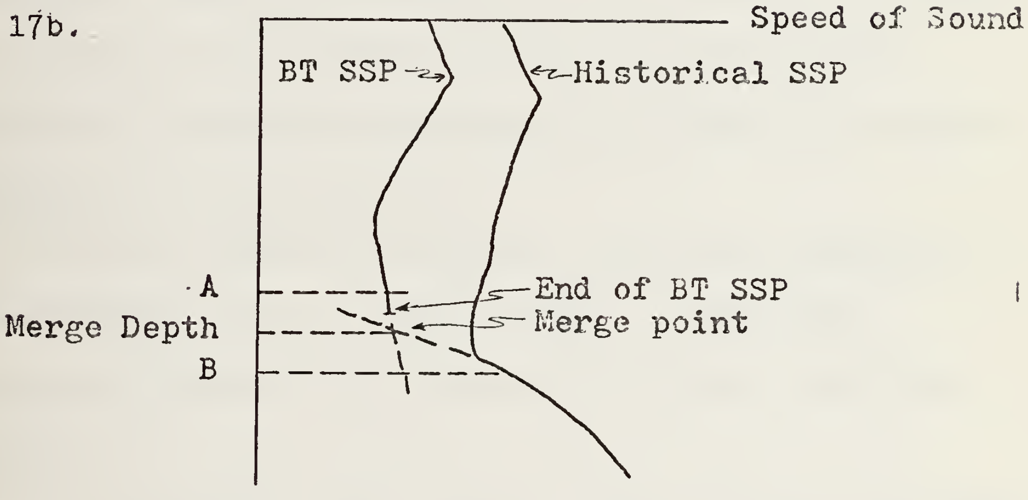
Mode 0 gives an automatic search for and plotting of convergence zone critical rays. The minimum source emission angle that will produce a bottom bounce, and the minimum (inside) and maximum (outside) convergence zone annulus ranges (if CZ is present) are stored.

Mode 1 gives the same computation as Mode 0 except that the ray traces are not plotted.

17a.



17b.



17c.

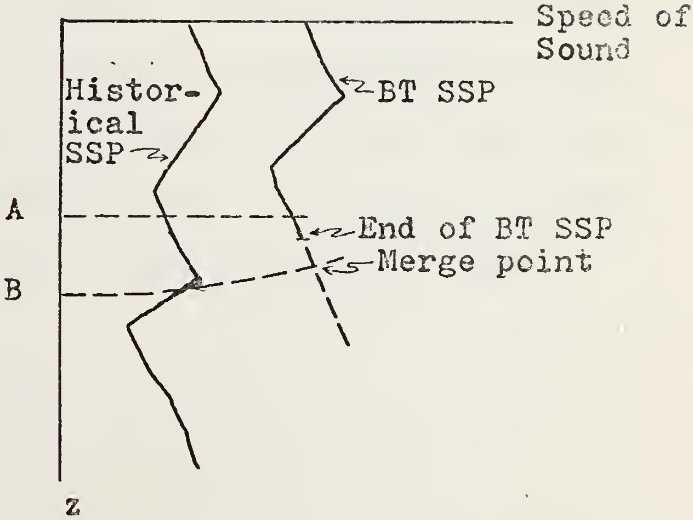


figure 17. Illustration of Merging techniques for Speed of Sound Profiles.

Mode 2: the operator enters twice the minimum and maximum emission angles to be traced from the source along with twice the incremental angle between. Doubling the desired angles and angle increment is necessary since the program internally halves all input angles prior to conversion to radians and storing. When the manual input plotting is completed, the program changes to Mode 1 to determine the critical parameters to be used by follow-on programs.

C. Program Mode 0 is intended to be the primary Mode for fleet use. Mode 1 is intended for use when a ray trace is not desired. Mode 2 is intended to be used for ray trace plots of specific source emission angles as well as for determination of critical parameters for follow-on programs - it is foreseen as a training aid.

D. If you have made an incorrect input and entered it with the CONTINUE, press: GO TO, LABEL, B, CONTINUE. Re-enter the ray trace input parameters starting with the Mode indicator.

E. It is possible, under certain sound velocity profile conditions, for the ray trace program in the automatic modes to trace a ducted ray to the end of the plot while searching for the convergence zone critical ranges. If this situation should occur you must check the stored convergence zone ranges as follows:

1. Press: X←( ), 008, ↑, 2000, ÷.

This calls out the minimum convergence zone range and converts it from yards to nautical miles.

2. Compare the value in the Y-register with the minimum convergence zone range indicated on the ray trace plot. If they differ considerably,

a. Enter the minimum convergence zone range from the ray trace plot;

b. Press: ↑, 2000, x (multiply), Y→( ), 008.

This converts the ray trace plot minimum CZ range from nautical miles to yards and stores it in the appropriate storage register.

3. Press X←( ), 009, ↑, 2000, ÷.

This calls out the maximum CZ range and converts it to nautical miles.

4. Compare the value in the Y-register with the maximum CZ range off the ray trace plot. If they differ considerably;

a. Enter the maximum CZ range from the ray trace plot.

b. Press: ↑, 2000, X (multiply), Y→( ), 009.

This converts the ray trace plot maximum CZ range from nautical miles to yards and stores it in the appropriate storage register.

5. Proceed with the transmission loss/probability of detection program.

F. If you want to do another ray trace and plot using the same sound speed profile but different input parameters:

1. Press: GO TO, LABEL, B, CONTINUE.

2. Enter the new ray trace inputs starting with the Mode indicator.

G. "SEE NOTE 3" and "END" will be printed on the output tape and the calculator's X, Y, and Z registers will illuminate when the ray trace portion of the program is completed.

H. "NO CZ", "SEE NOTE 3", and "END" will be printed on the output tape to indicate that the program has ended and there is no convergence zone present.

I. If "NO CZ", "SEE NOTE 3", and "END" is printed out and you would like a ray trace plot, you will have to use Mode 2 and manual emission angle parameters to get a plot (see E above). At the end of the Mode 2 plots "NO CZ", "SEE NOTE 3", and "END" will be printed on the output tape.

J. If another sound velocity profile is to be entered for subsequent ray trace plots, press: END, CONTINUE, to start the entire sequence again.

Note 3

A. Change the plotting paper.

B. The TL/PD magnetic cards are loaded in the same manner as the SSP/Ray Trace cards.

C. Press: STOP, END to initialize the program function. This sequence is used when a TLOSS/PD entering error is made, or a new TLOSS/PD plot is to be generated based on the same SSP/Ray Trace generated data.

D. Source frequency is to be entered in Hertz (Hz).

E. Figure of Merit: ensure that you use all the same units of reference (μPa, or μb). DO NOT add 100 to the computed FOM.

F. System Sigma

If the variances of the sonar equation terms are known, enter the square root of the sum of the variances. If the variances are unknown, choose one of the following:

1. Use 6 dB if ambient noise measurements have been made, and submarine speed and type are known.

2. Use 8 dB if ambient noise is estimated from a forecast, submarine speed is known to within 3 kts, and submarine type is known.

3. Use 10 dB if ambient noise is estimated from forecasts and submarine speed and type are uncertain.

G. Wave Height (IWH)

Sea State	Term	Height of Wave (ft)
1	Calm	0 to 1
2	Wavelets	1 to 2
3	Slight	2 to 4
4	Moderate	4 to 8
5	Rough	8 to 13
6	Very rough	13 to 20
7	High	20 to 30
8	Very high	30 to 45
9	Phenomenal	over 45

H. A bottom type indicator (MGS) of 1 indicates little sound loss; a bottom type indicator of 9 indicates a large sound loss.

I. If new TLOSS/PD data is to be entered to make additional plots from the same ray trace data, press STOP, END. Change the plotting paper, then press CONTINUE. Then enter the new data.

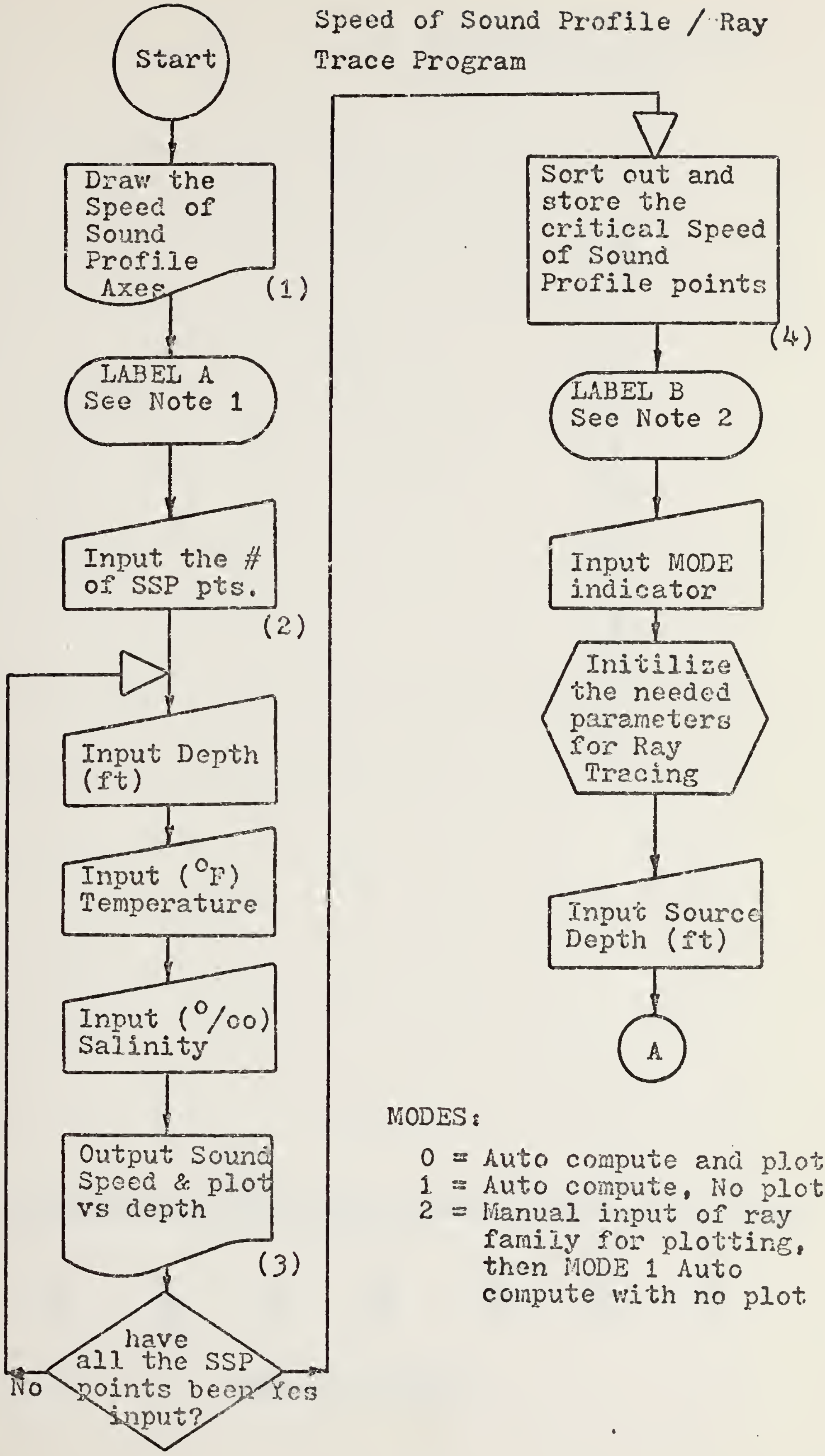
J. If a new ray trace is to be generated from the old SSP information after the transmission loss/probability of detection program has been run: press: STOP, END, LOAD. Load the SSP/Ray Trace program using the magnetic cards, change the plotting paper, press: GO TO, LABEL, B, CONTINUE, then follow the instructions in Note 2.

APPENDIX D

Flow charts, program listings, and output from the HP9810A and IBM 360 are included within this Appendix.

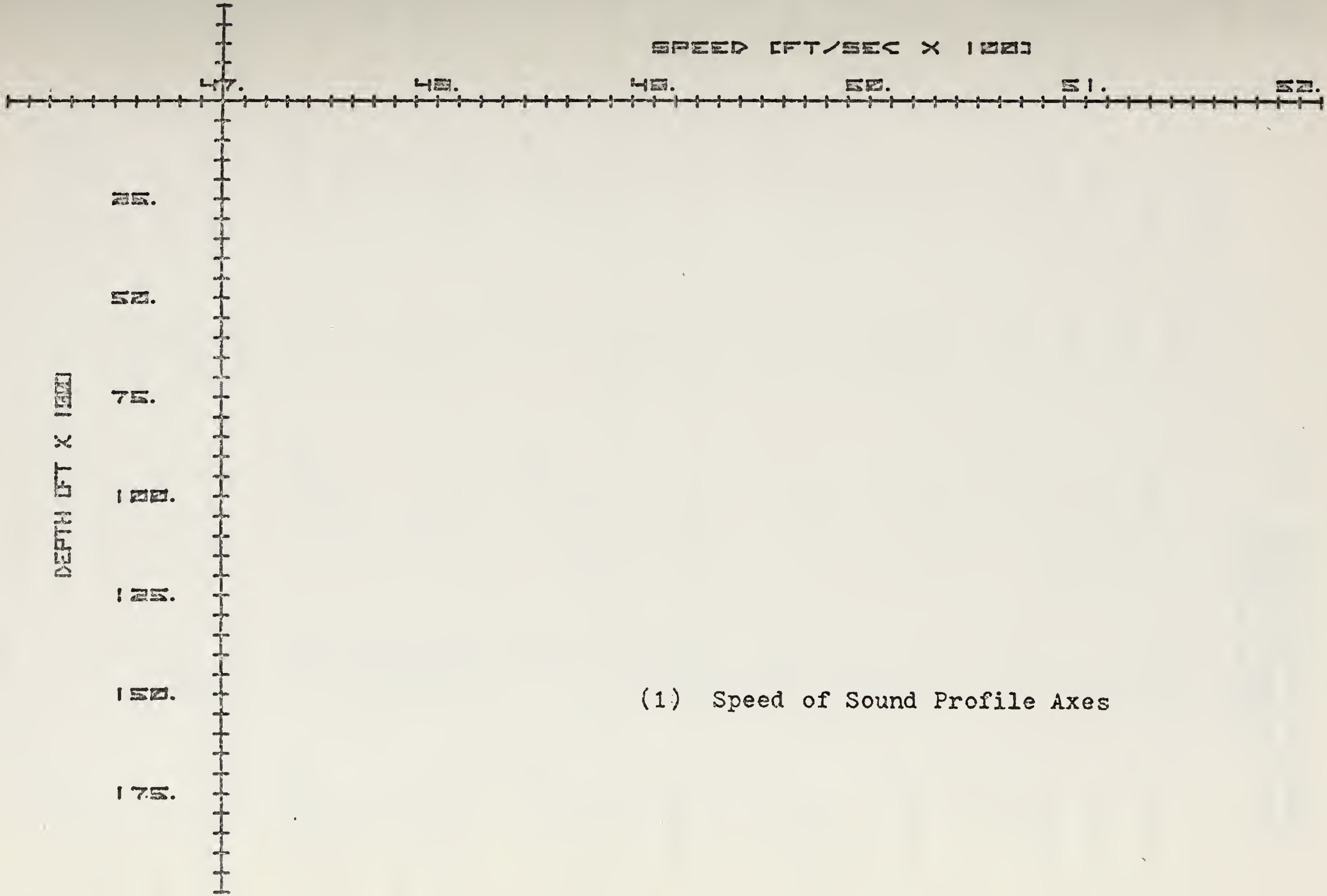
Speed of Sound Profile / Ray Trace Program
flow charts and sample outputs

Speed of Sound Profile / Ray Trace Program


Start
Draw the Speed of Sound Profile Axes
(1)
LABEL A See Note 1
Input the # of SSP pts.
(2)
Input Depth (ft)
Input (°F) Temperature
Input (°/oo) Salinity
Output Sound Speed & plot vs depth
(3)
have all the SSP points been input?
No
Yes
Sort out and store the critical Speed of Sound Profile points
(4)
LABEL B See Note 2
Input MODE indicator
Initilize the needed parameters for Ray Tracing
Input Source Depth (ft)
A

MODES:

0 = Auto compute and plot
1 = Auto compute, No plot
2 = Manual input of ray family for plotting, then MODE 1 Auto compute with no plot



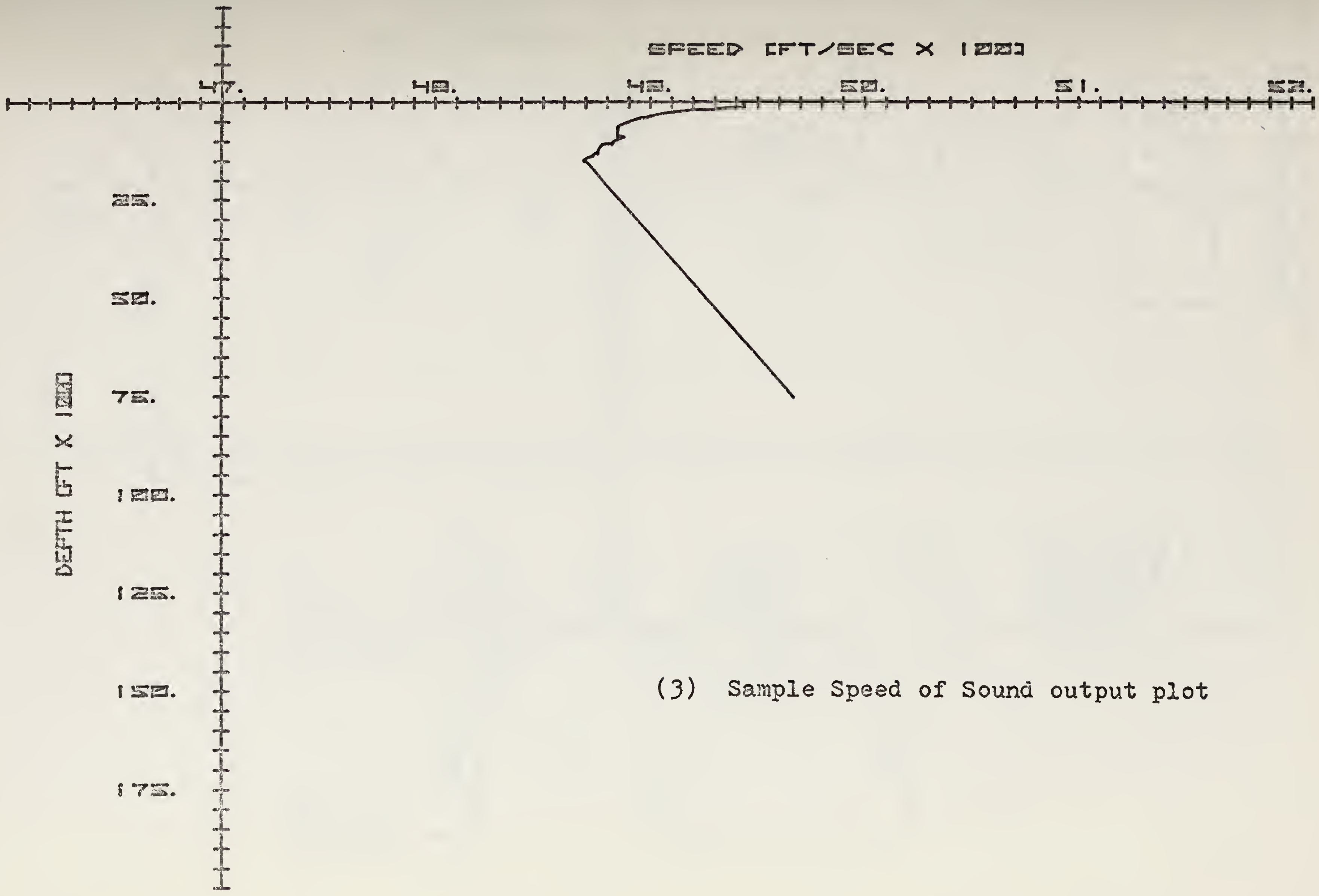
(1) Speed of Sound Profile Axes

(2) **Sample Speed of Sound Profile program input / printer output**

```
SSP
SEE NOTE 1

NR PTS
             15.00*
DEPTH
              0.00*
TEMP
             58.60*
SALIN
             35.00*
SPD
          4941.70

DEPTH
            120.00*
TEMP
             58.60*
SALIN
             35.00*
SPD
          4943.64

DEPTH
            175.00*
TEMP
             57.00*
SALIN
             35.00*
SPD
          4935.15

DEPTH
            200.00*
TEMP
             56.00*
SALIN
             35.00*
SPD
          4929.58

DEPTH
            225.00*
TEMP
             54.00*
SALIN
             35.00*
SPD
          4917.78
```

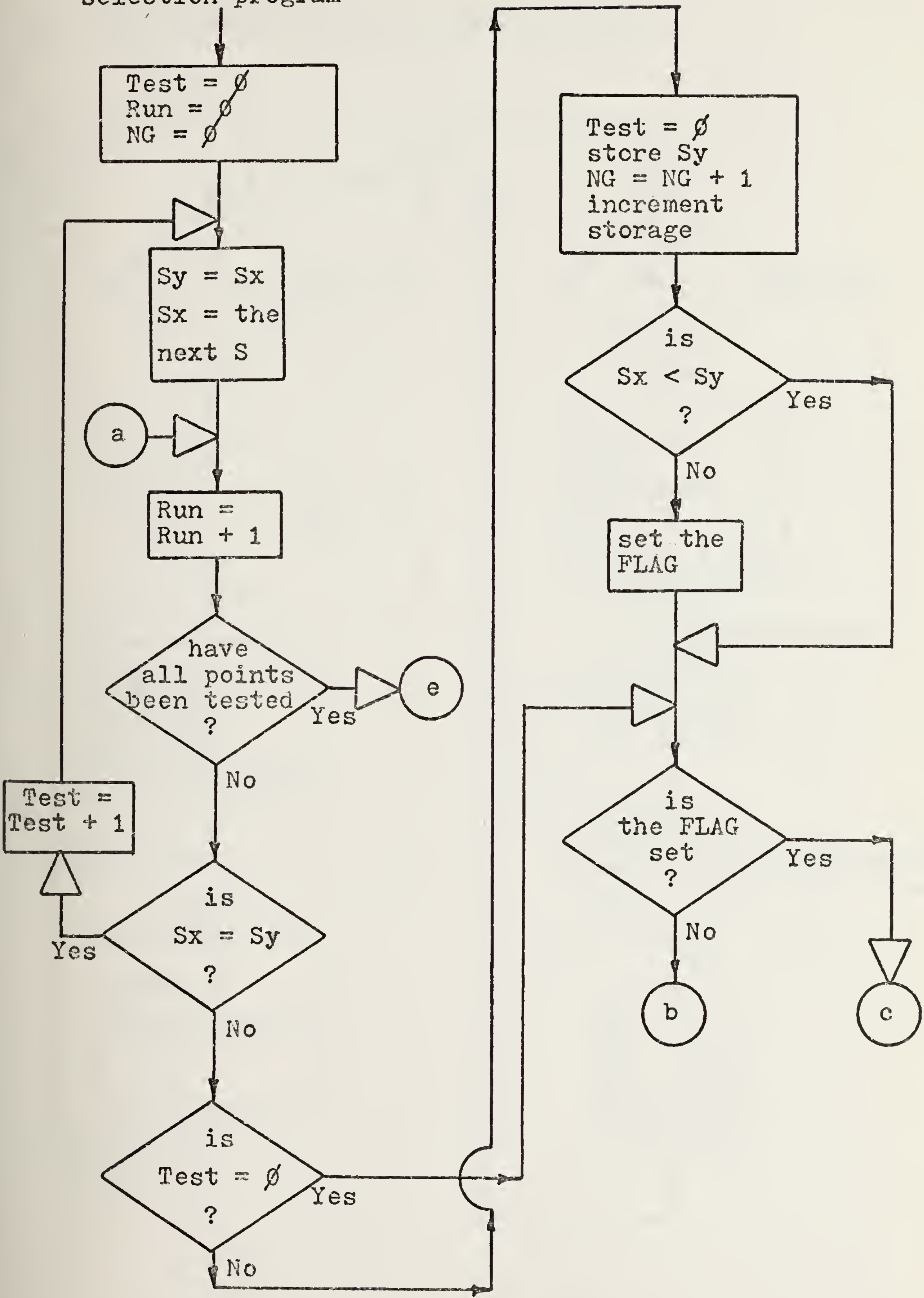
```
DEPTH
            400.00*
TEMP
             50.50*
SALIN
             35.00*
SPD
          4898.36

DEPTH
            650.00*
TEMP
             47.90*
SALIN
             35.00*
SPD
          4885.12

DEPTH
            870.00*
TEMP
             47.30*
SALIN
             35.00*
SPD
          4884.56

DEPTH
            900.00*
TEMP
             47.70*
SALIN
             35.00*
SPD
          4887.76

DEPTH
           1075.00*
TEMP
             46.50*
SALIN
             35.00*
SPD
          4882.36
```

```
DEPTH
           1100.00*
TEMP
             45.80*
SALIN
             35.00*
SPD
          4877.91

DEPTH
           1300.00*
TEMP
             45.00*
SALIN
             35.00*
SPD
          4875.51

DEPTH
           1380.00*
TEMP
             44.50*
SALIN
             35.00*
SPD
          4873.26

DEPTH
           1500.00*
TEMP
             43.70*
SALIN
             35.00*
SPD
          4869.49

DEPTH
           7500.00*
TEMP
             43.70*
SALIN
             35.00*
SPD
          4966.70

SEE NOTE 2
```

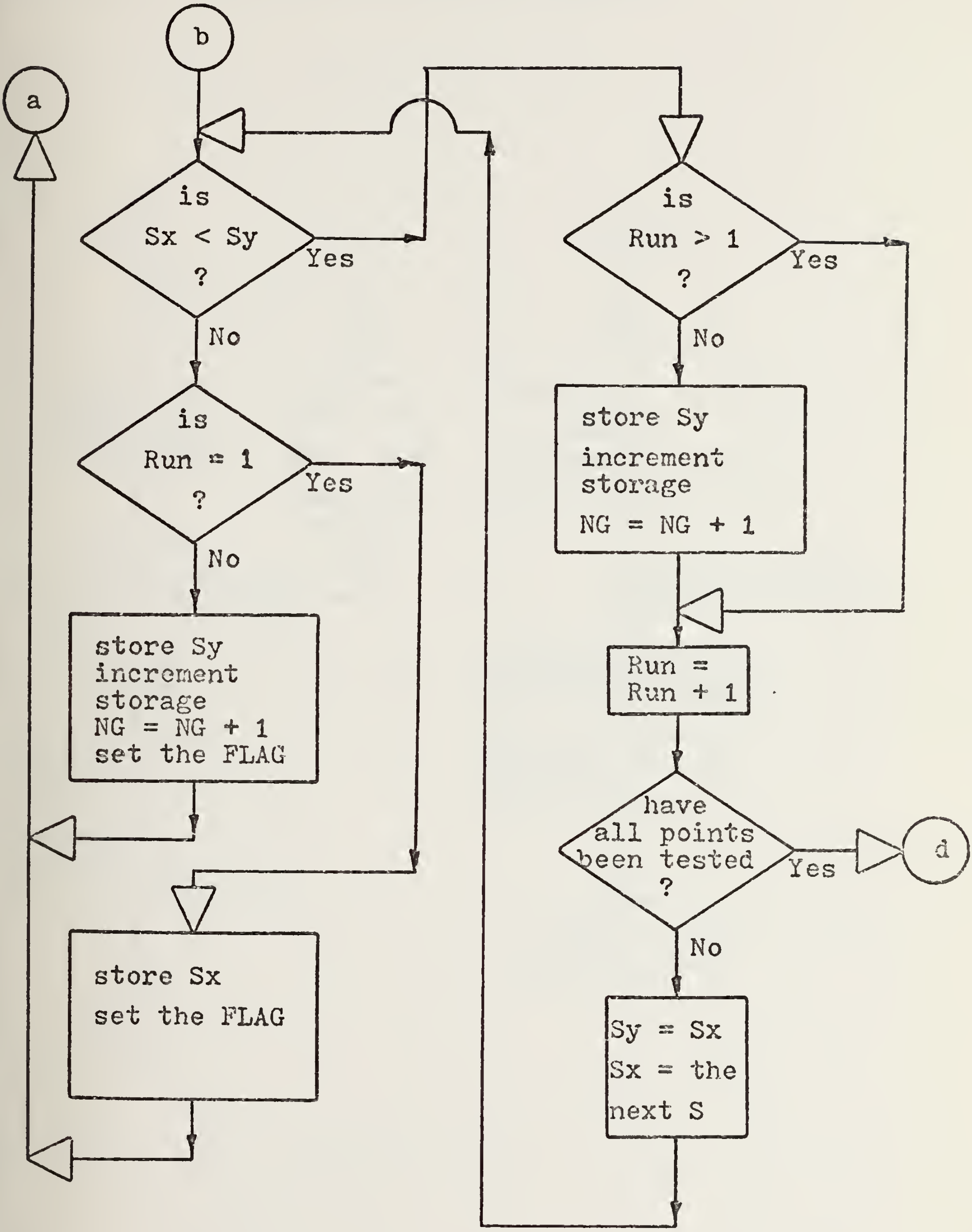


(3) Sample Speed of Sound output plot

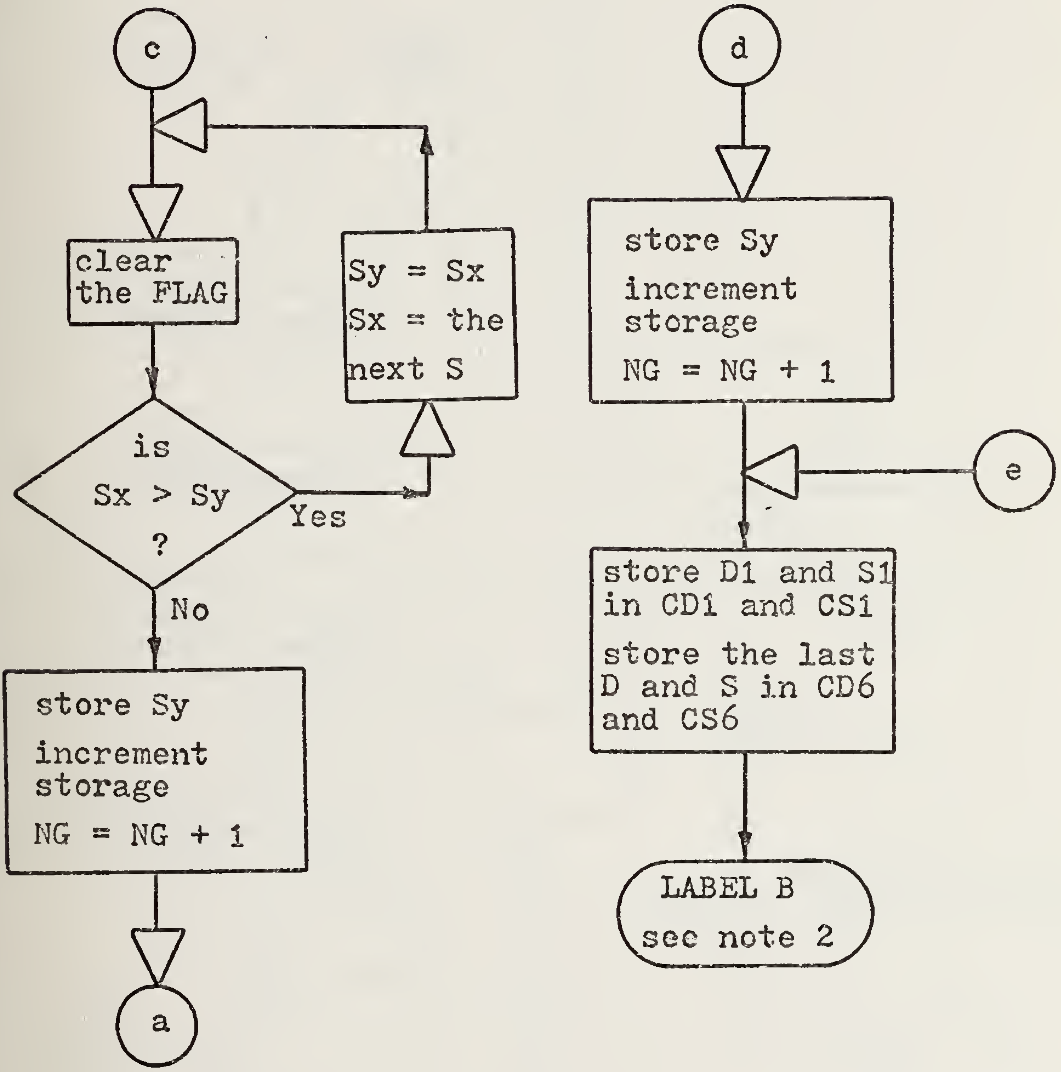
(4) SSP critical points selection program



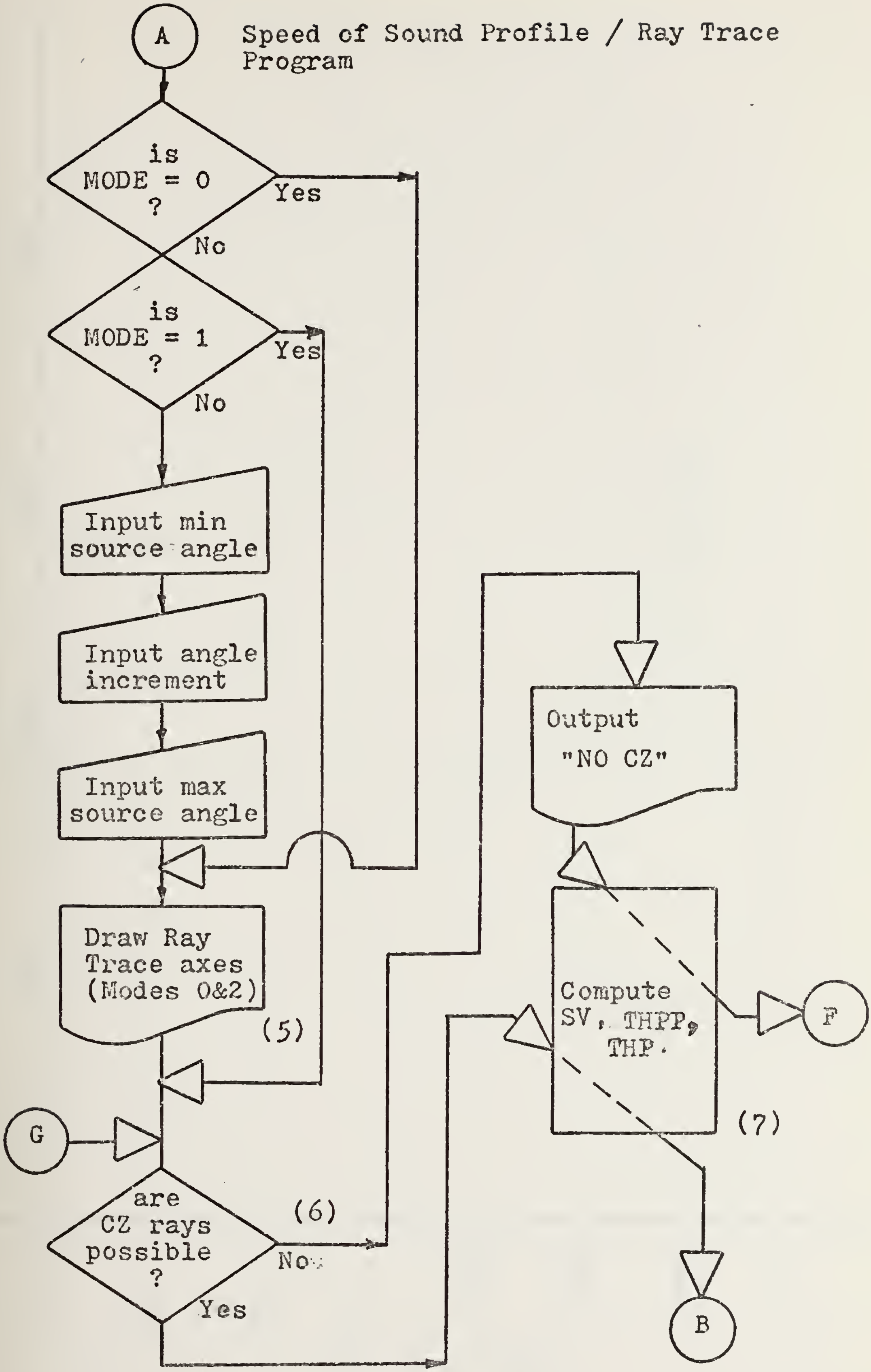
(4) SSP critical points selection program

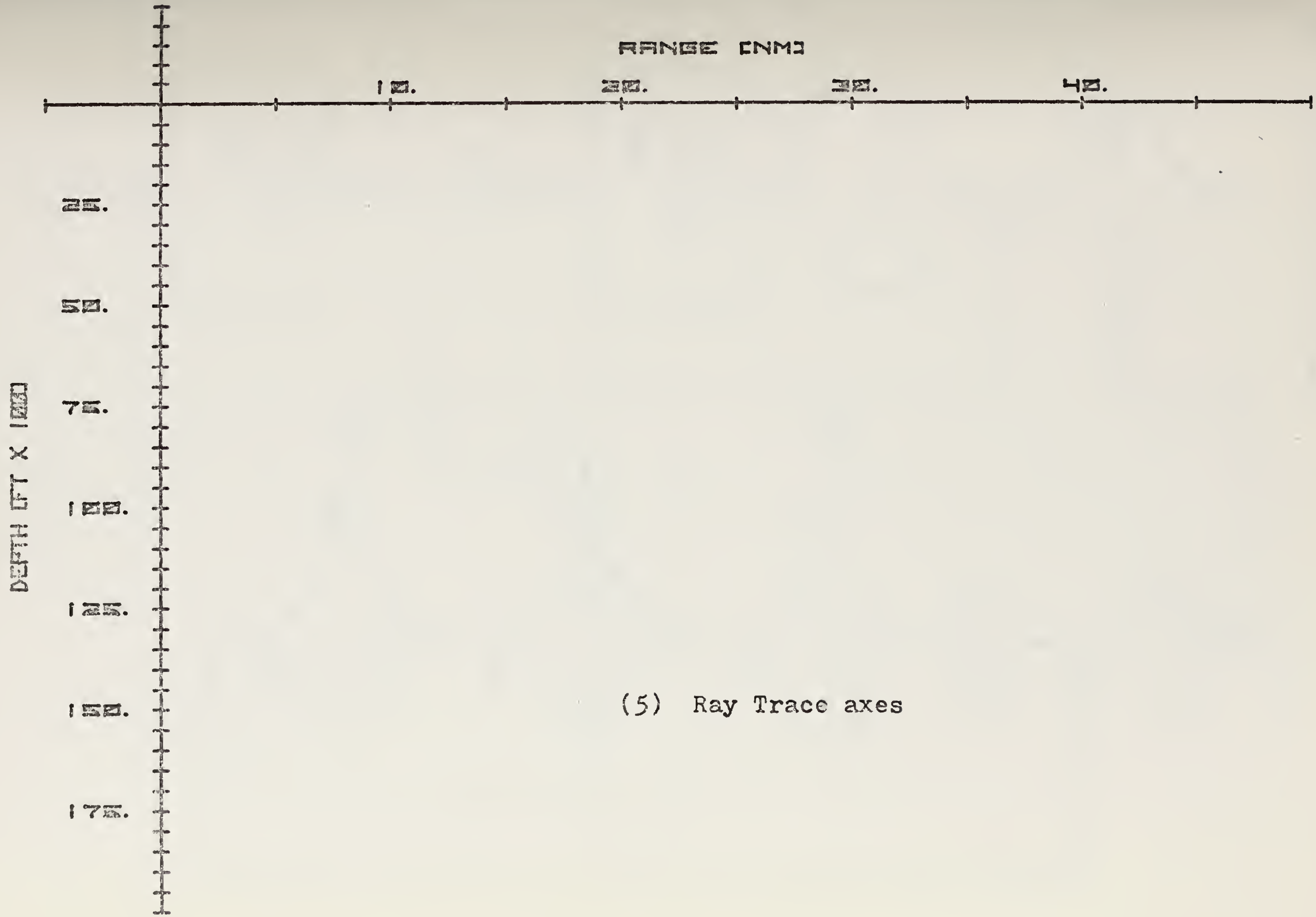


(4) SSP critical points selection program



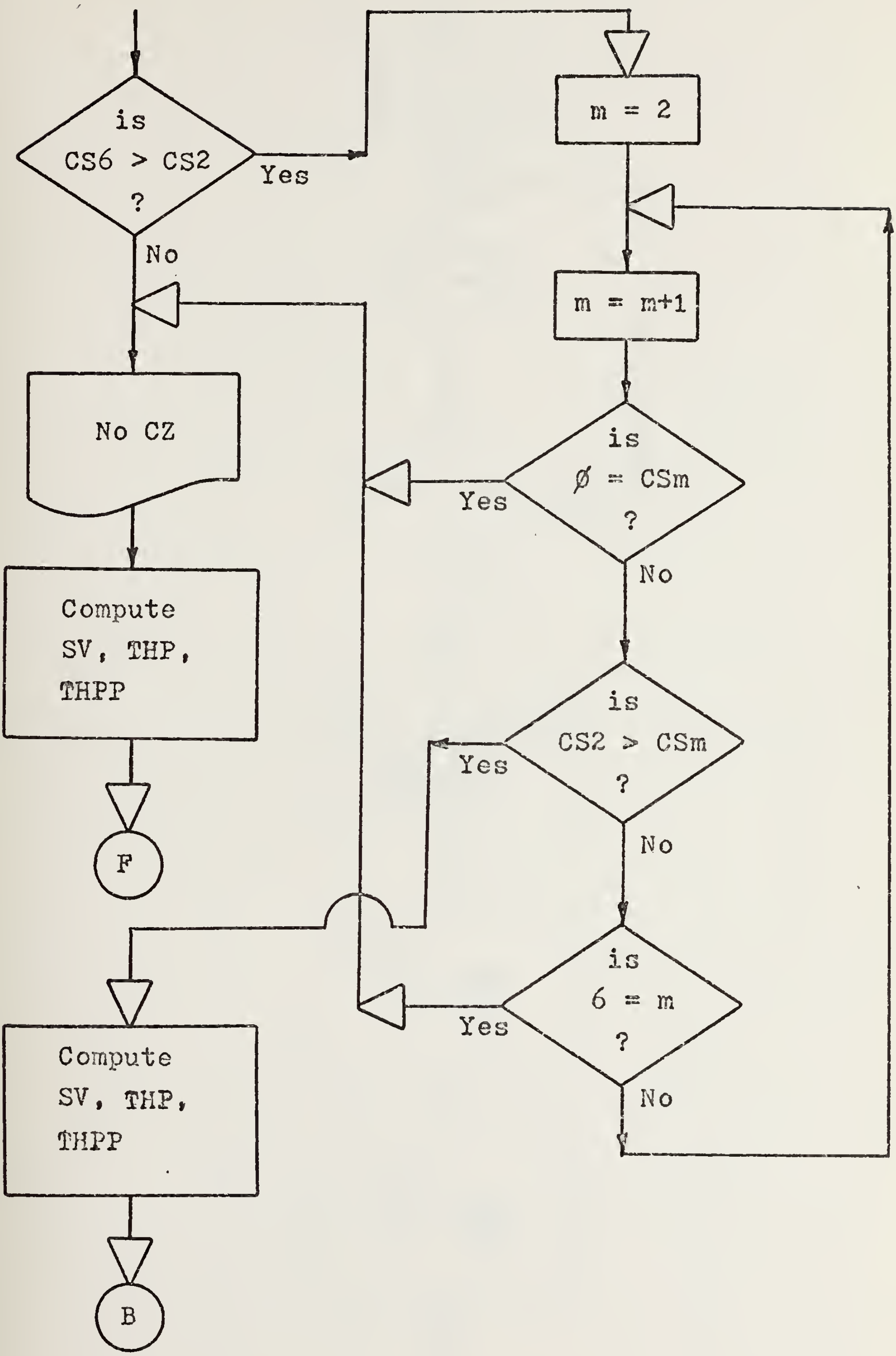
Speed of Sound Profile / Ray Trace Program



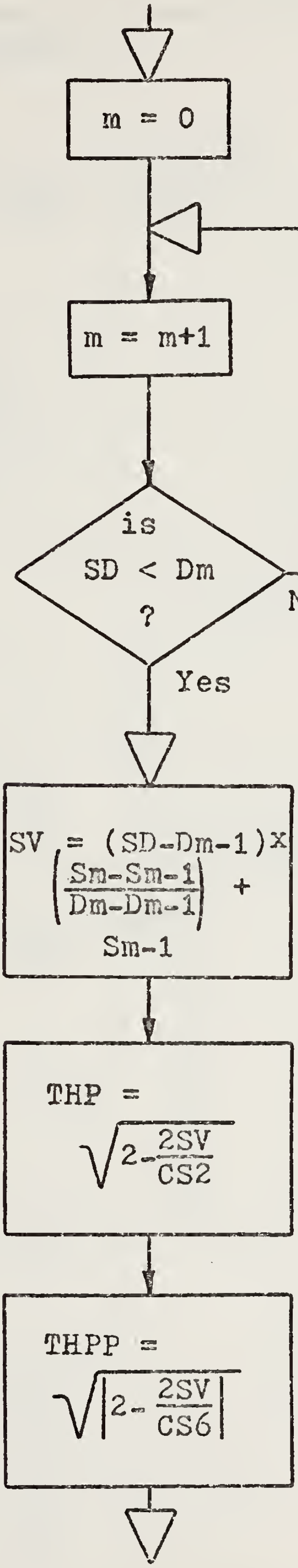


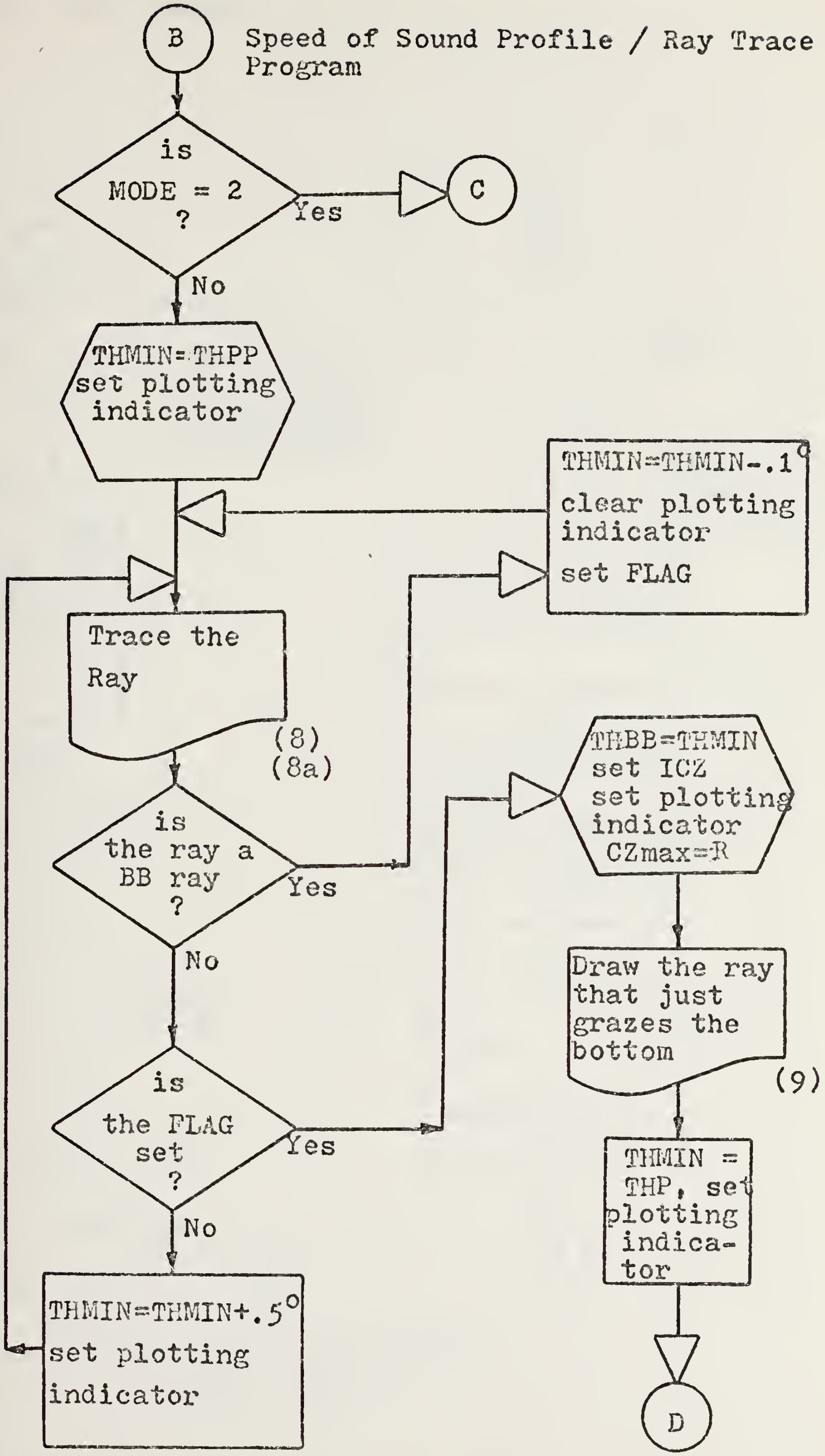
(5) Ray Trace axes

(6) Convergence Zone Test



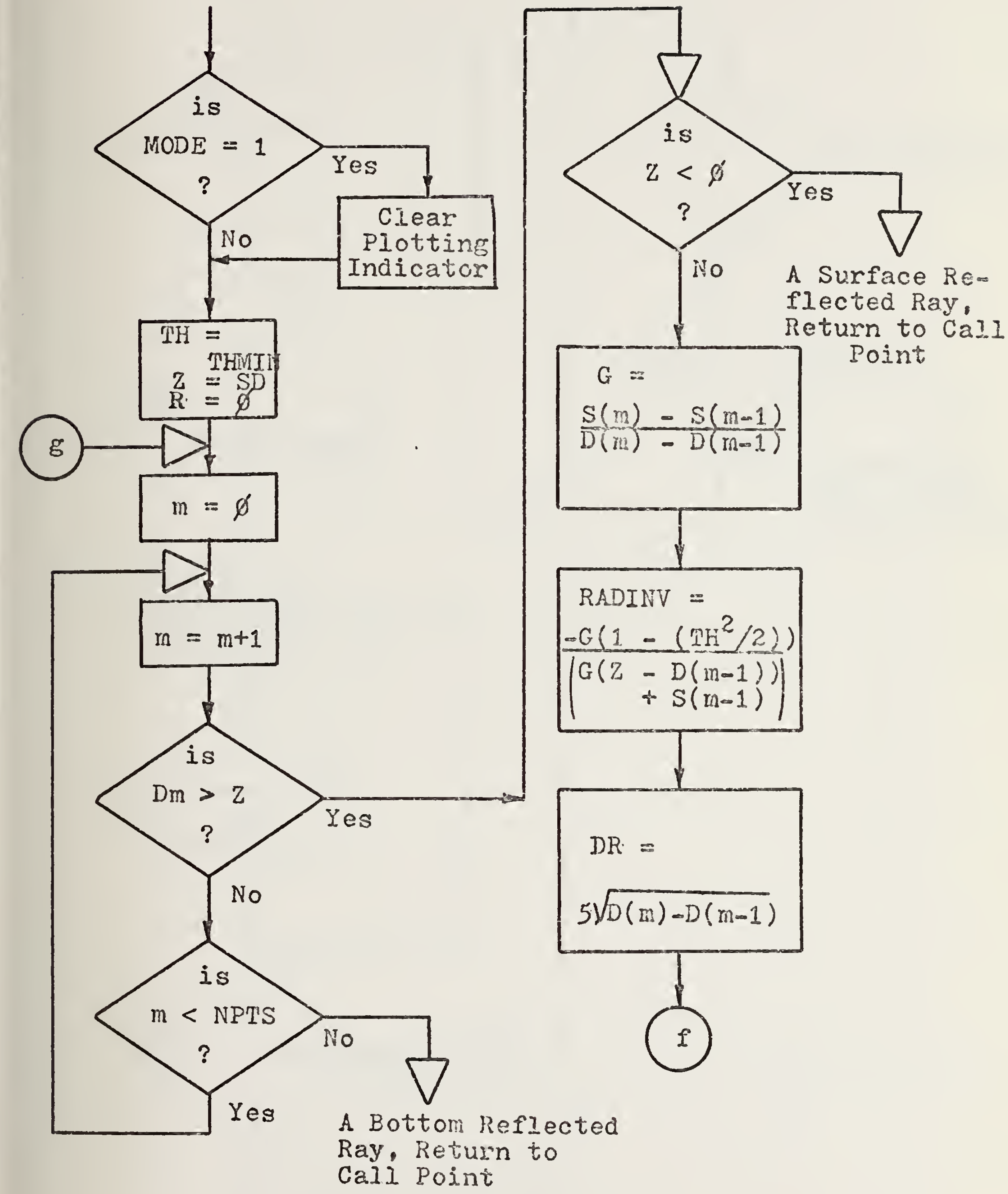
(7) Computation of SV, THP, THPP



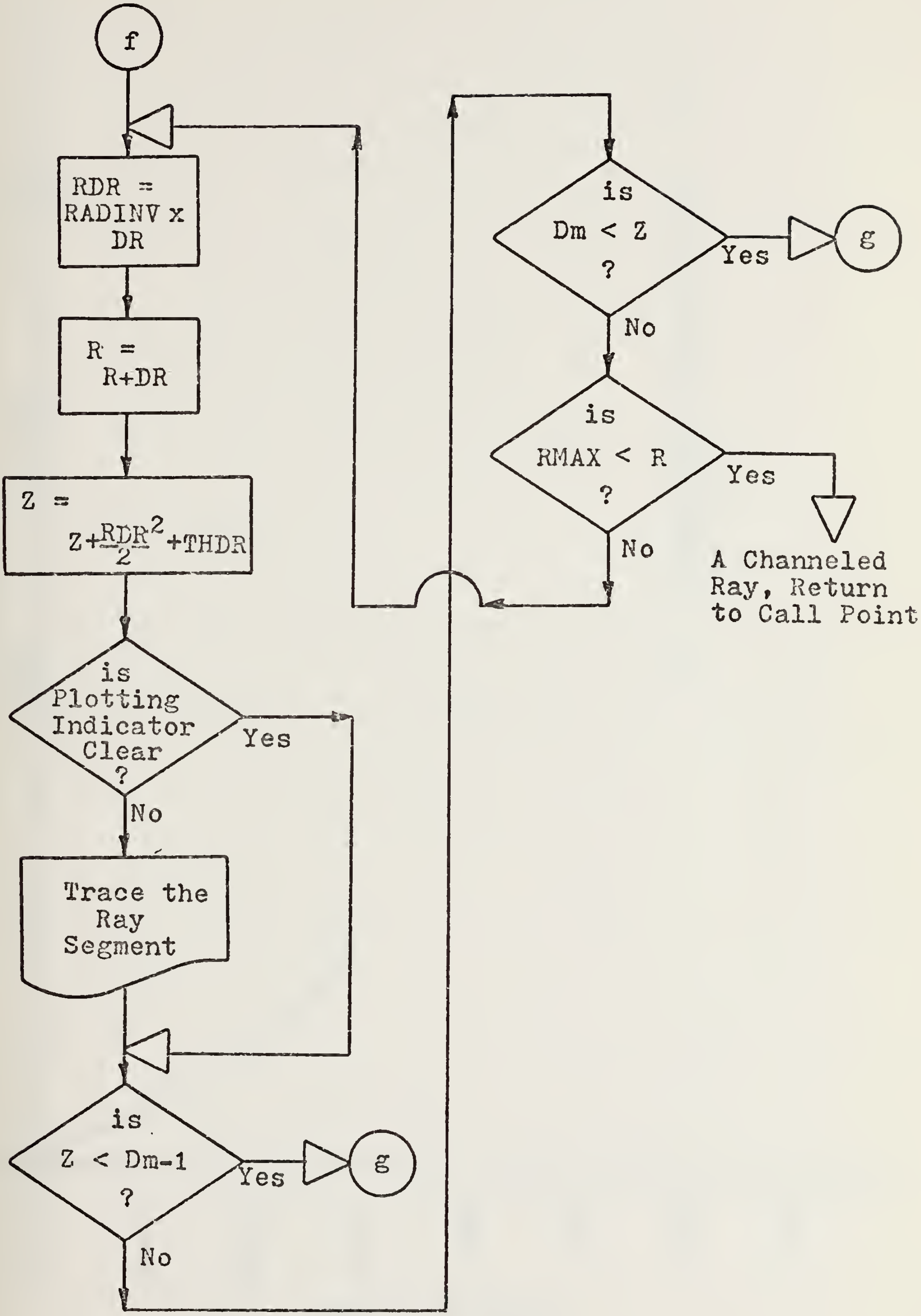


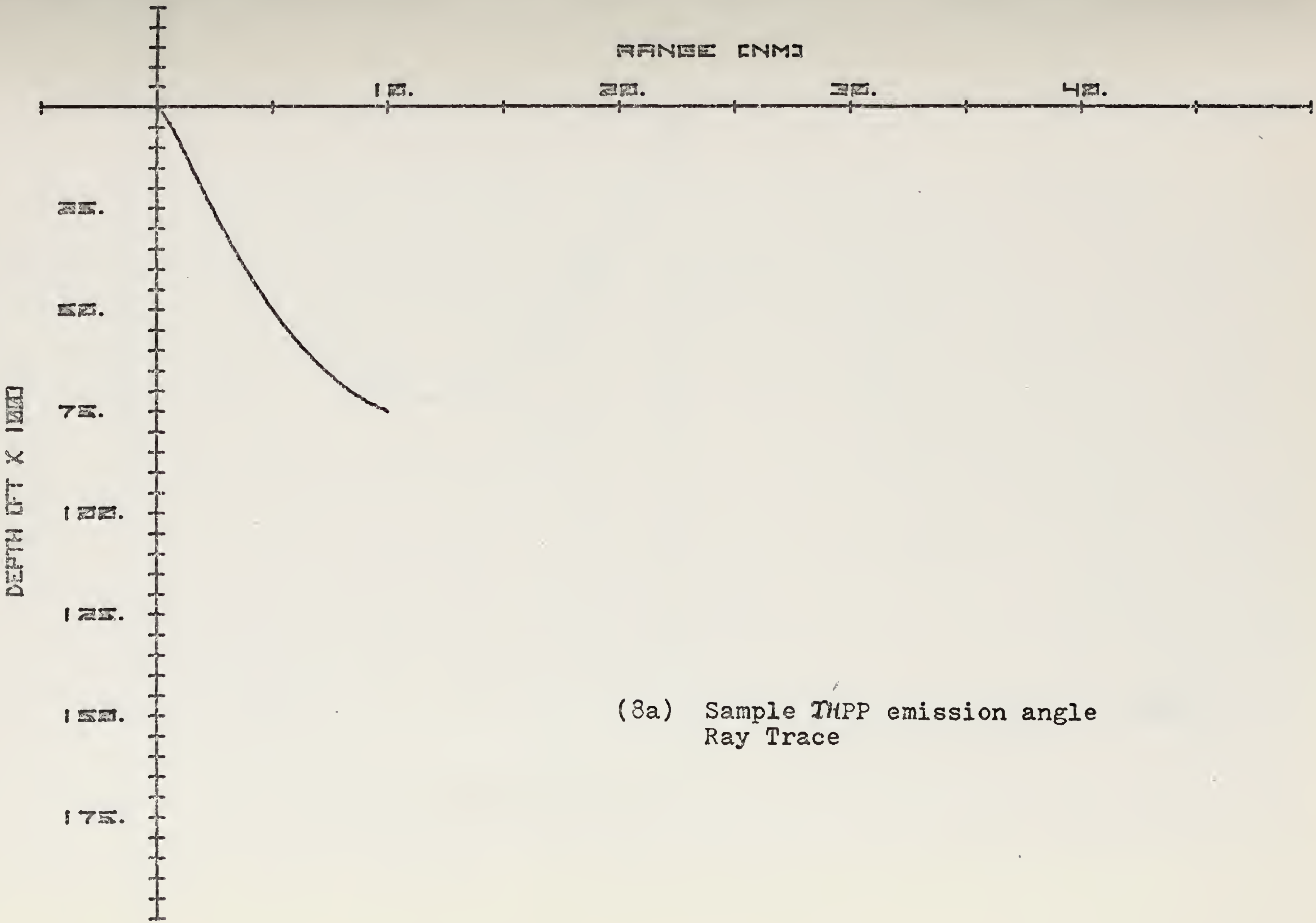
Speed of Sound Profile / Ray Trace Program

(8) Ray Trace Program

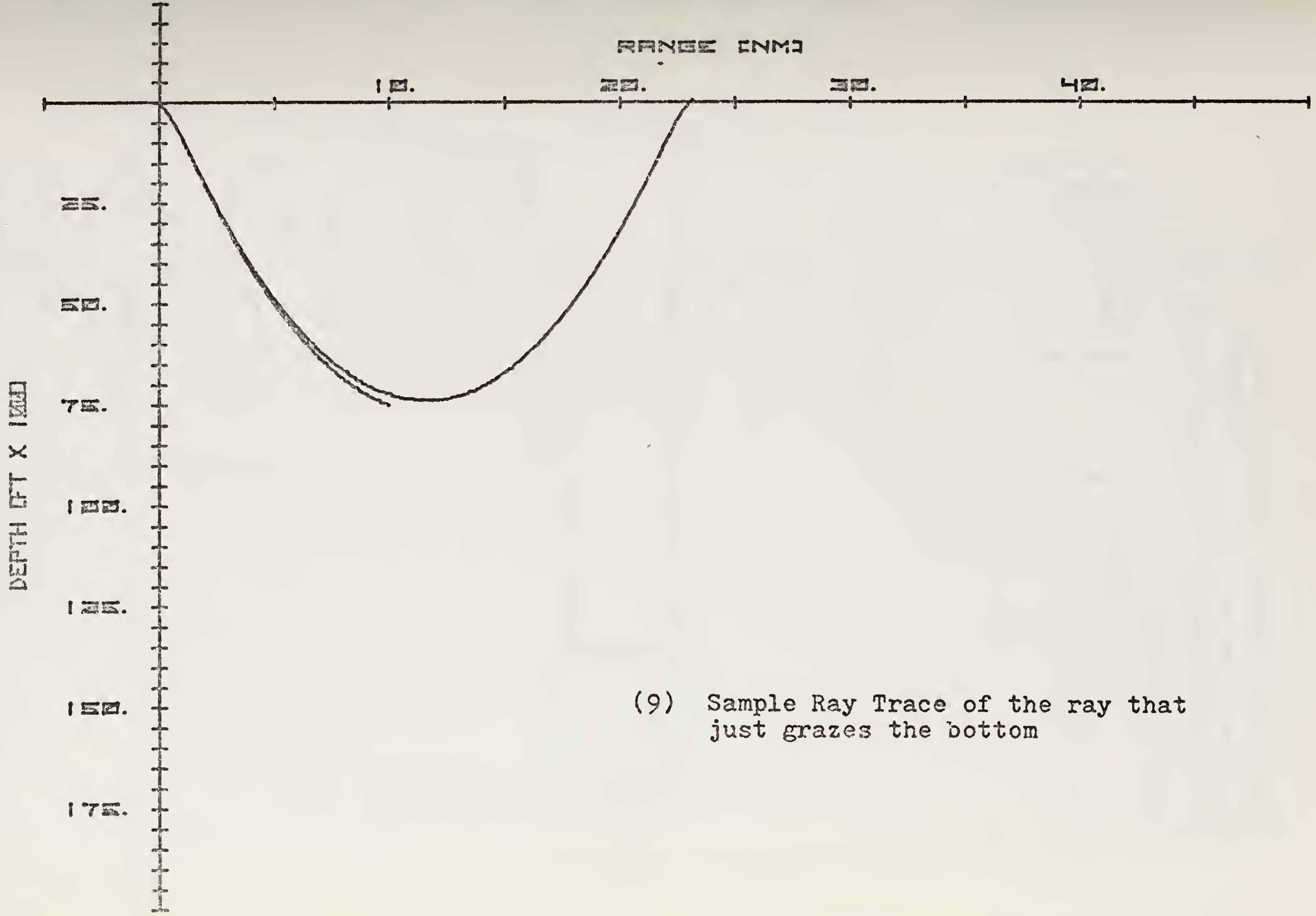

is MODE = 1 ?
Yes
Clear Plotting Indicator
No
TH = THMIN
Z = SD
R = 0
g
m = 0
m = m+1
is Dm > Z ?
Yes
No
is m < NPTS ?
No
Yes
A Bottom Reflected Ray, Return to Call Point
is Z < 0 ?
Yes
A Surface Reflected Ray, Return to Call Point
No
G = (S(m) - S(m-1))/(D(m) - D(m-1))
RADINV = -G(1 - (TH²/2)) / (G(Z - D(m-1)) + S(m-1))
DR = 5√(D(m)-D(m-1))
f

(8) Ray Trace Program



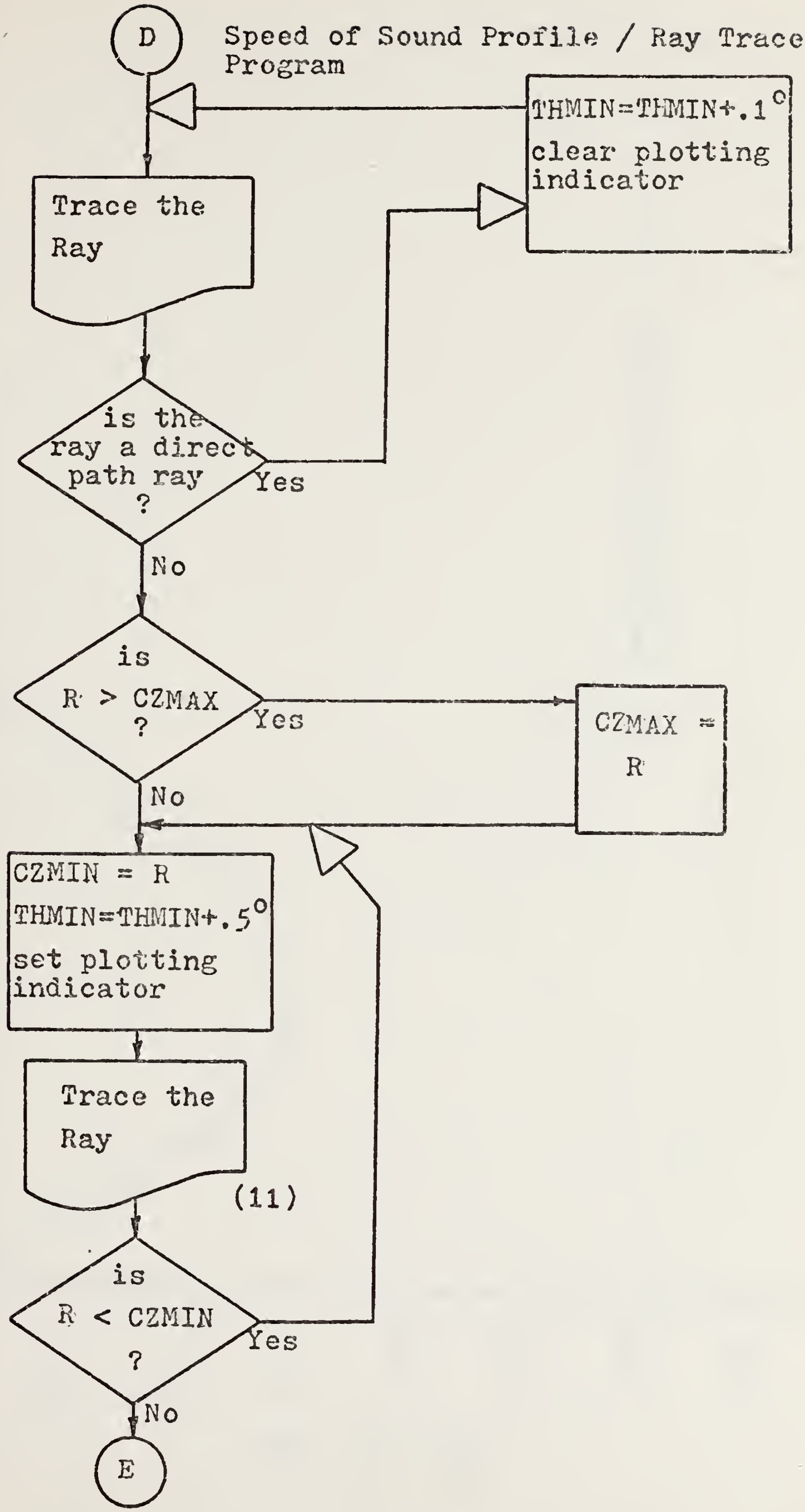


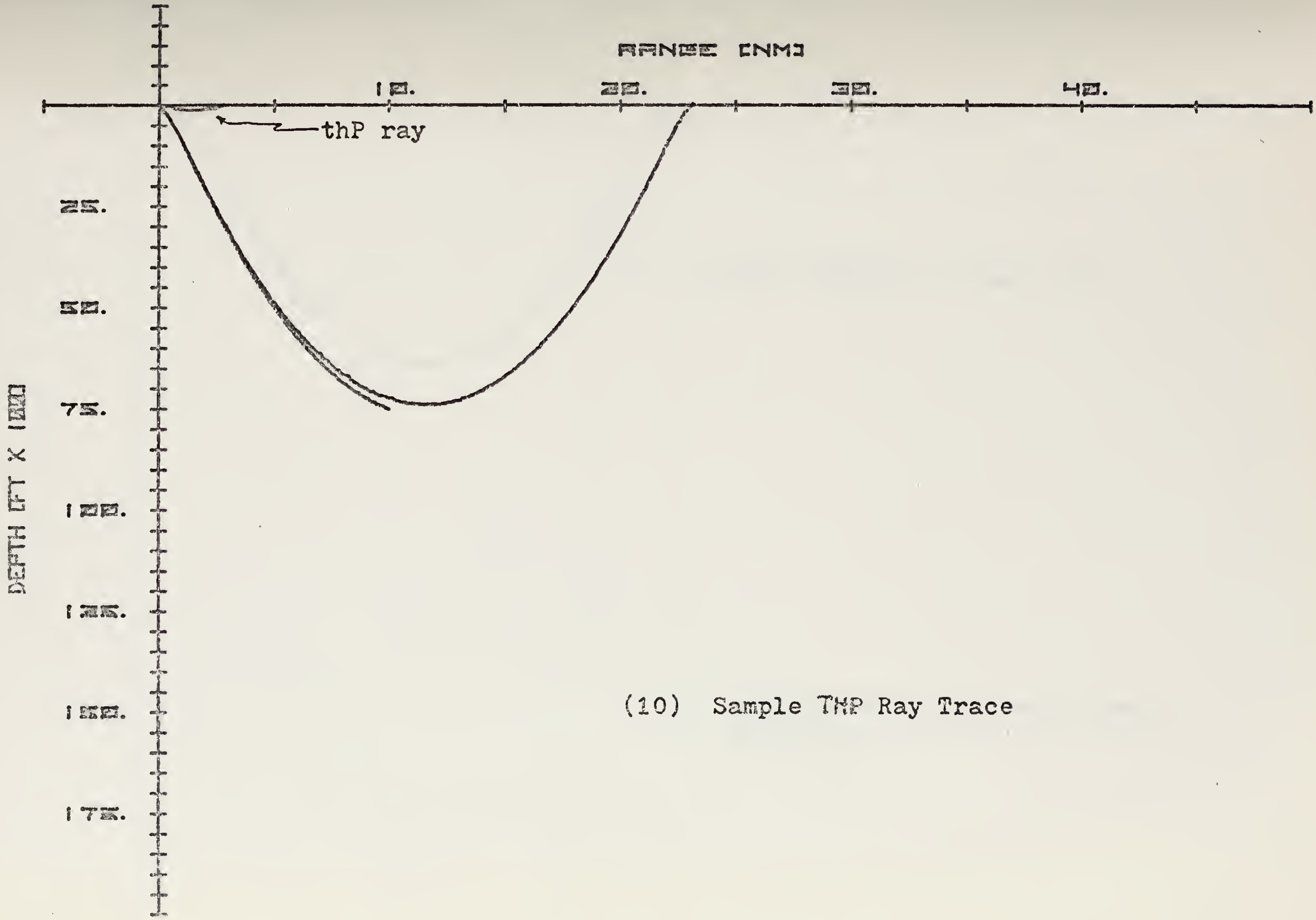
(8a) Sample THPP emission angle
Ray Trace



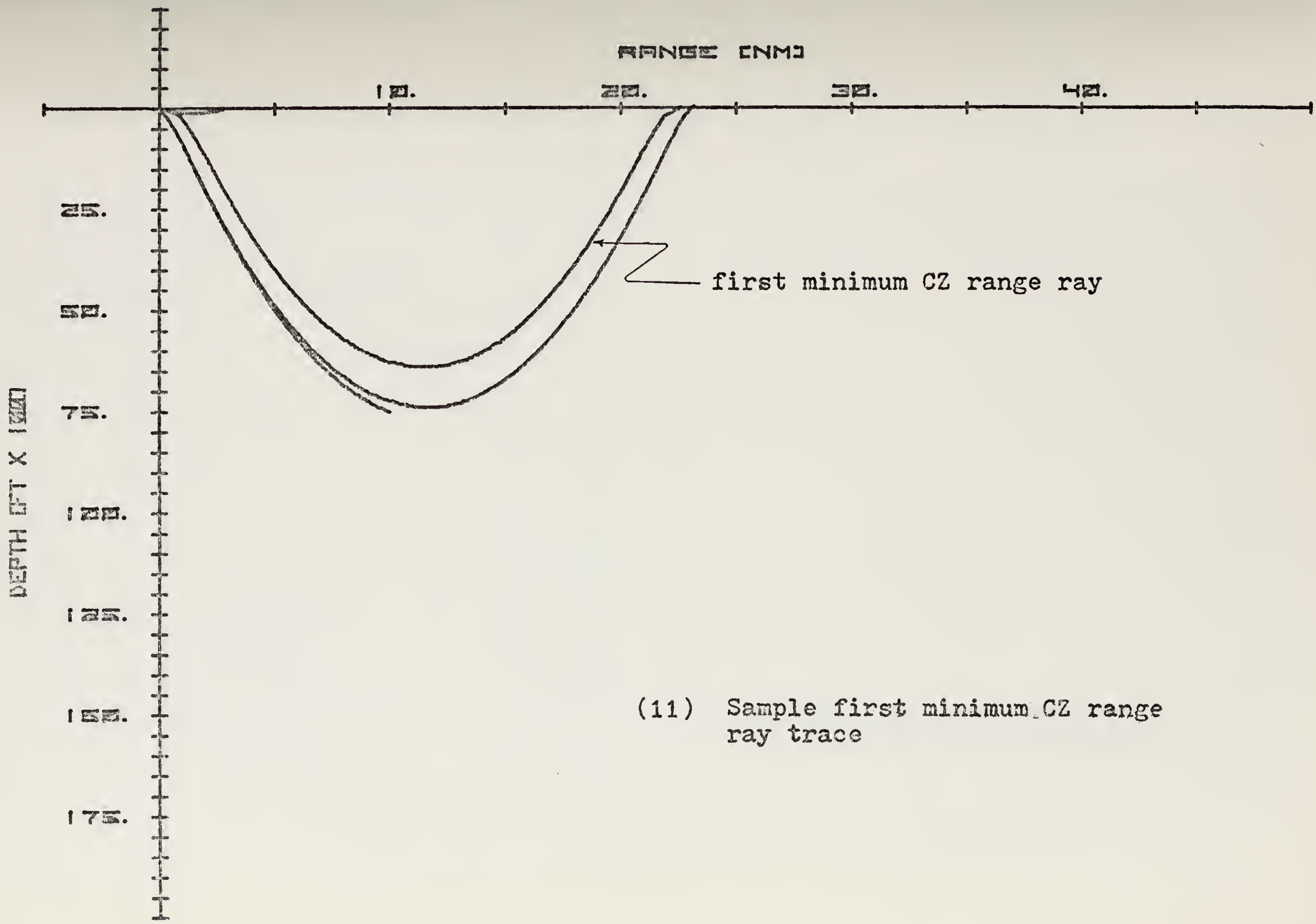
(9) Sample Ray Trace of the ray that just grazes the bottom

Speed of Sound Profile / Ray Trace Program

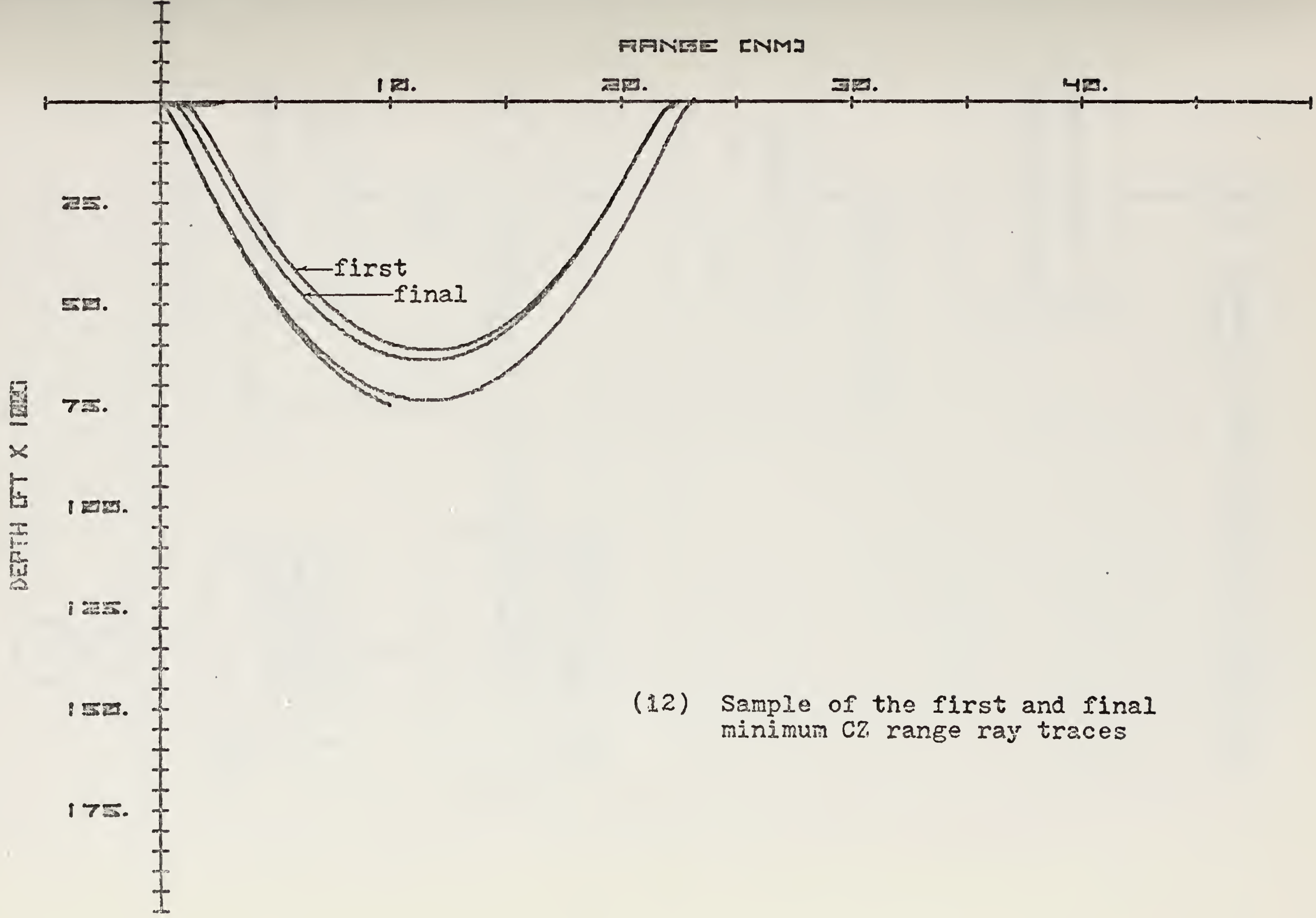




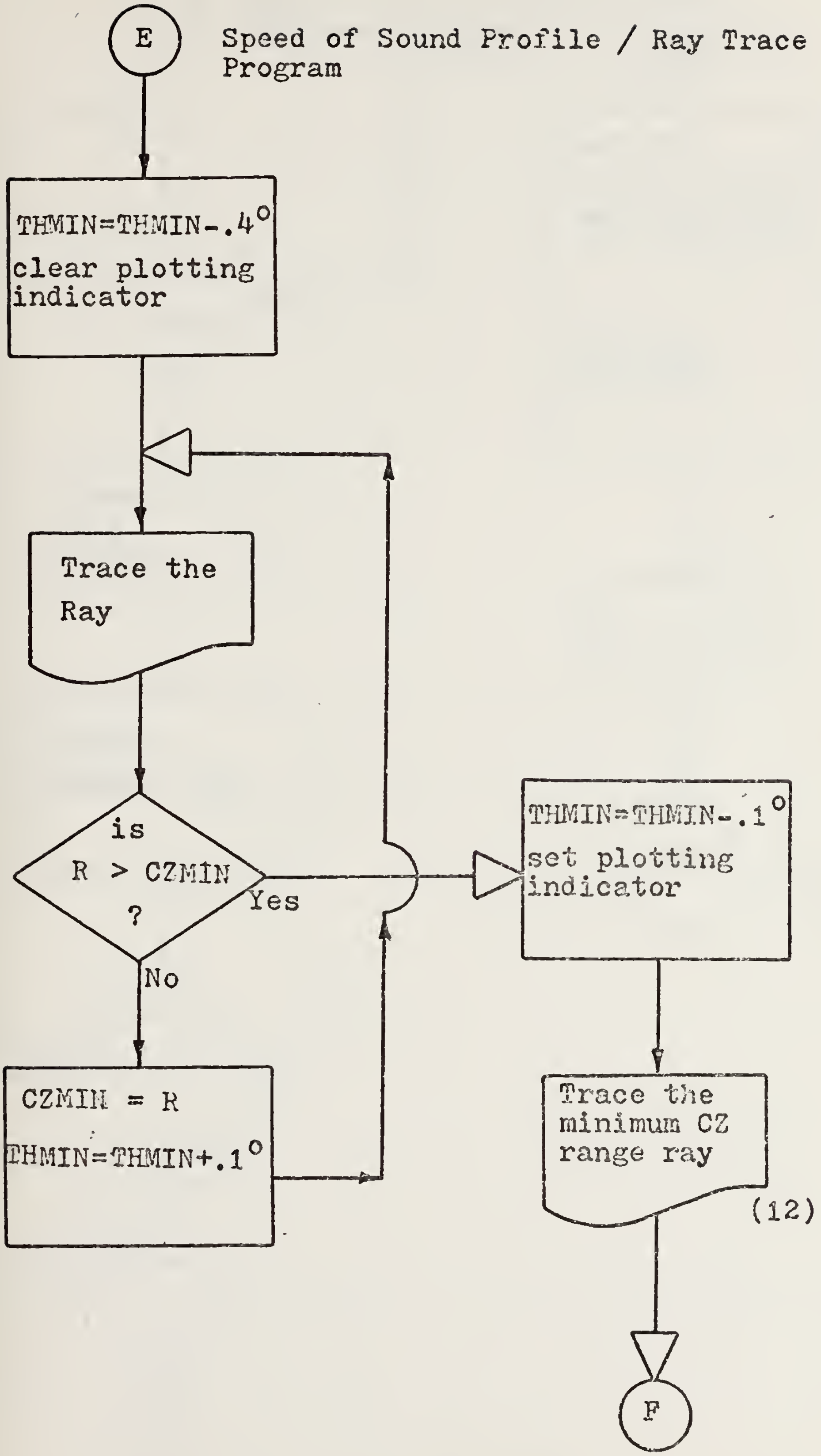
(10) Sample THP Ray Trace

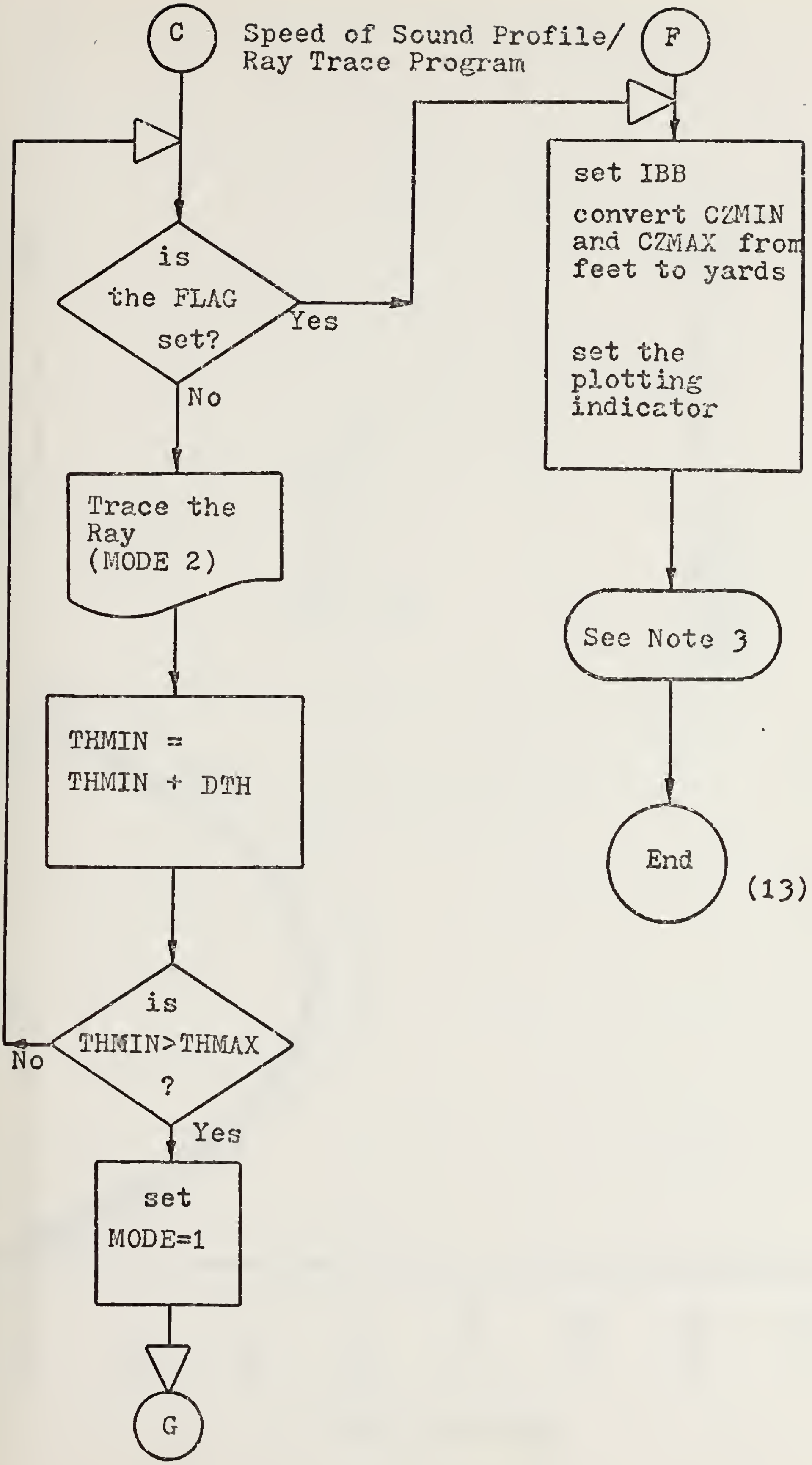


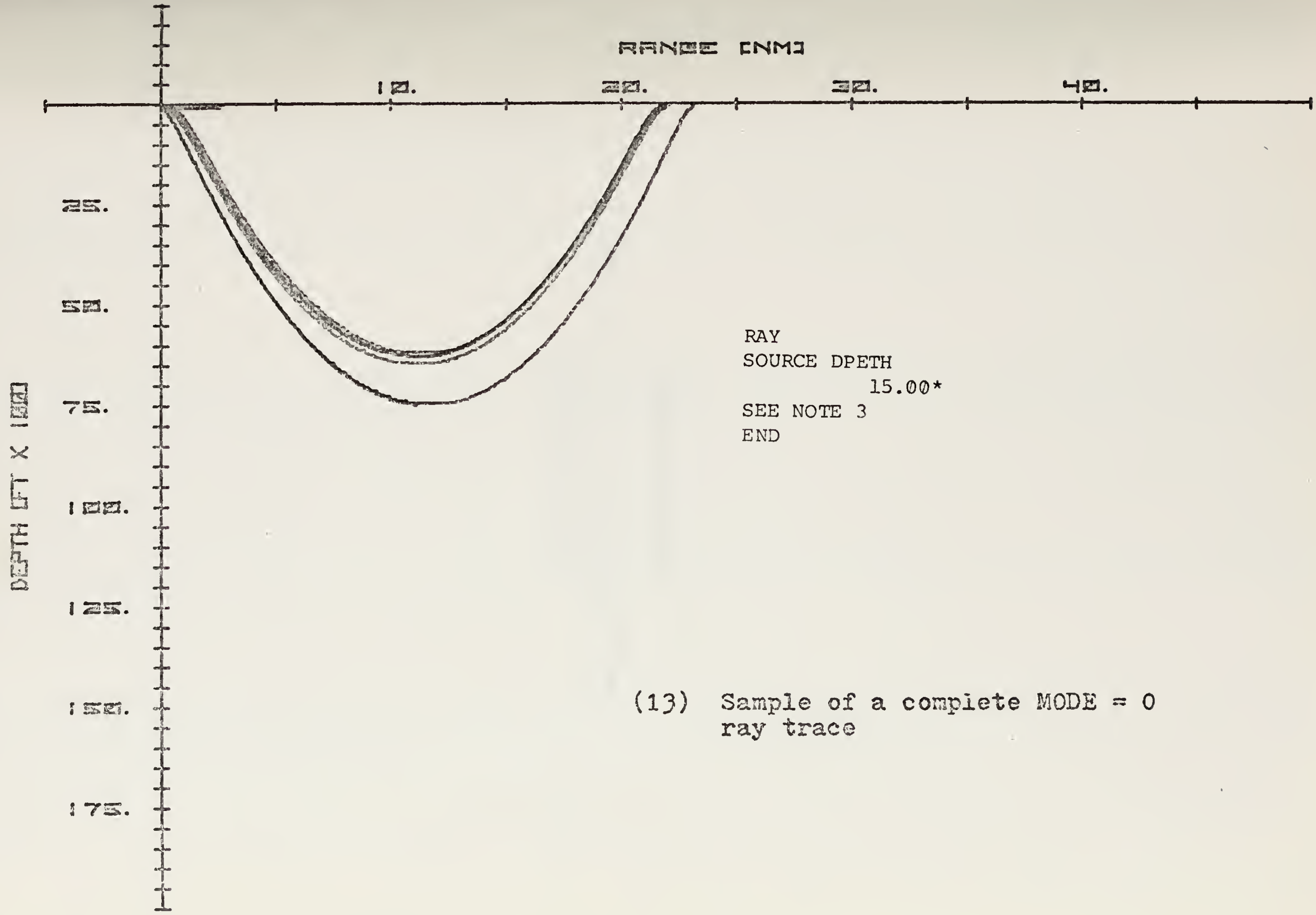
(11) Sample first minimum CZ range ray trace



(12) Sample of the first and final minimum CZ range ray traces


Speed of Sound Profile / Ray Trace Program


C
Speed of Sound Profile/
Ray Trace Program
F
is
the FLAG
set?
Yes
No
set IBB
convert CZMIN
and CZMAX from
feet to yards
set the
plotting
indicator
Trace the
Ray
(MODE 2)
See Note 3
THMIN =
THMIN + DTH
End
(13)
is
THMIN>THMAX
?
No
Yes
set
MODE=1
G



(13) Sample of a complete MODE = 0 ray trace

PEAPS HP 9810A
Speed of Sound Profile/Ray Trace
Program Listing

```
0000--GTO---44
0001-- 4 ---04
0002-- 5 ---05
0003--YTO---40
0004--IND---31
0005-- b ---14
0006-- 3 ---03
0007--XTO---23
0008-- - ---34
0009-- a ---13
0010-- 6 ---06
0011--XTO---23
0012-- - ---34
0013-- b ---14
0014--XFR---67
0015--IND---31
0016-- a ---13
0017--XTO---23
0018--IND---31
0019-- b ---14
0020-- 3 ---03
0021--XTO---23
0022-- + ---33
0023-- a ---13
0024-- 7 ---07
0025--XTO---23
0026-- + ---33
0027-- b ---14
0028-- 1 ---01
0029--XTO---23
0030-- + ---33
0031-- 2 ---02
0032--S/R---77
0033--XFR---67
0034--IND---31
0035-- a ---13
0036-- UP---27
0037-- 2 ---02
0038--XTO---23
0039-- + ---33
0040-- a ---13
0041--XFR---67
0042--IND---31
0043-- a ---13
0044--S/R---77
0045--FMT---42
0046-- 1 ---01
0047-- 8 ---10
0048-- 0 ---00
0049-- 5 ---05
0050-- 2 ---02
0051-- 1 ---01
0052-- 0 ---00
0053-- UP---27
0054-- 4 ---04
0055-- 6 ---06
0056-- 0 ---00
0057-- 0 ---00
0058--FMT---42
0059-- 1 ---01
0060-- 2 ---02
0061-- 2 ---02
0062-- 5 ---05
0063-- 0 ---00
0064-- 0 ---00
0065-- UP---27
0066--CHS---32
0067-- 2 ---02
0068--EEX---26
0069-- 4 ---04
0070--FMT---42
0071-- 1 ---01
0072-- 3 ---03
0073-- 0 ---00
0074-- UP---27
0075-- 4 ---04
0076-- 7 ---07
0077-- 0 ---00
0078-- 0 ---00
0079--FMT---42
0080-- 1 ---01
0081-- UP---27
0082-- 1 ---01
0083-- 0 ---00
0084--FMT---42
0085-- 1 ---01
0086-- 5 ---05
0087-- 5 ---05
0088-- 0 ---00
0089-- 0 ---00
0090--FMT---42
0091-- 1 ---01
0092-- 6 ---06
0093-- . ---21
0094-- 1 ---01
0095-- 0 ---00
0096--FMT---42
0097-- 1 ---01
0098-- 1 ---01
0099-- 1 ---01
0100-- 2 ---02
0101-- 7 ---07
0102-- 5 ---05
0103-- UP---27
0104-- 4 ---04
0105-- 9 ---11
0106-- 0 ---00
0107-- 0 ---00
0108--FMT---42
0109-- 1 ---01
0110-- UP---27
0111--FMT---42
0112-- 1 ---01
0113--FMT---42
0114--YTO---40
0115-- π ---56
0116-- E ---60
0117-- E ---60
0118-- D ---63
0119--CNT---47
0120--X<Y---52
0121-- F ---16
0122--XTO---23
0123--DIV---35
0124--YTO---40
0125-- E ---60
0126-- C ---61
0127--CNT---47
0128-- YE---24
0129--CNT---47
0130-- 1 ---01
0131-- 0 ---00
0132-- 0 ---00
0133--PSE---57
0134--FMT---42
0135-- 4 ---04
0136-- 6 ---06
0137-- 9 ---11
0138-- 0 ---00
0139--XTO---23
0140-- a ---13
0141-- 4 ---04
0142-- 7 ---07
0143--XTO---23
0144-- b ---14
0145-- 3 ---03
0146-- 0 ---00
0147-- 0 ---00
0148-- UP---27
0149-- a ---13
0150--FMT---42
0151-- 1 ---01
0152-- UP---27
0153-- b ---14
0154--FMT---42
0155-- 1 ---01
0156--PNT---45
0157-- 1 ---01
0158-- 0 ---00
0159-- 0 ---00
0160--XTO---23
0161-- + ---33
```

```
0162-- a ---13
0163-- 1 ---01
0164--XTO---23
0165-- + ---33
0166-- b ---14
0167-- b ---14
0168-- UP---27
0169-- 5 ---05
0170-- 3 ---03
0171--X>Y---53
0172-- 0 ---00
0173-- 1 ---01
0174-- 4 ---04
0175-- 5 ---05
0176--FMT---42
0177-- 1 ---01
0178-- 9 ---11
0179--CHS---32
0180-- 1 ---01
0181-- 2 ---02
0182--EEX---26
0183-- 3 ---03
0184-- UP---27
0185-- 4 ---04
0186-- 6 ---06
0187-- 3 ---03
0188-- 0 ---00
0189--FMT---42
0190-- 1 ---01
0191-- UP---27
0192--FMT---42
0193-- 1 ---01
0194--FMT---42
0195-- D ---63
0196-- E ---60
0197-- π ---56
0198--XTO---23
0199-- H ---74
0200--CNT---47
0201--X<Y---52
0202-- F ---16
0203--XTO---23
0204--CNT---47
0205-- YE---24
0206--CNT---47
0207-- 1 ---01
0208-- 0 ---00
0209-- 0 ---00
0210--PSE---57
0211--FMT---42
0212--FMT---42
0213-- 1 ---01
0214-- 9 ---11
0215-- 2 ---02
0216-- 6 ---06
0217-- 0 ---00
0218-- 0 ---00
0219--CHS---32
0220--XTO---23
0221-- a ---13
0222-- 2 ---02
0223-- 5 ---05
0224--XTO---23
0225-- b ---14
0226-- a ---13
0227-- UP---27
0228-- 4 ---04
0229-- 6 ---06
0230-- 5 ---05
0231-- 0 ---00
0232--FMT---42
0233-- 1 ---01
0234-- UP---27
0235-- b ---14
0236--FMT---42
0237-- 1 ---01
0238--PNT---45
0239-- 2 ---02
0240-- 5 ---05
0241-- 0 ---00
0242-- 0 ---00
0243--XTO---23
0244-- - ---34
0245-- a ---13
0246-- 2 ---02
0247-- 5 ---05
0248--XTO---23
0249-- + ---33
0250-- b ---14
0251-- b ---14
0252-- UP---27
0253-- 2 ---02
0254--EEX---26
0255-- 2 ---02
0256--X>Y---53
0257-- 0 ---00
0258-- 2 ---02
0259-- 2 ---02
0260-- 6 ---06
0261-- 0 ---00
0262-- UP---27
0263-- 5 ---05
0264-- 0 ---00
0265-- 0 ---00
0266-- 0 ---00
0267--FMT---42
0268-- 1 ---01
0269-- UP---27
0270--LBL---51
0271-- A ---62
0272--CLR---20
0273-- 9 ---11
0274-- 9 ---11
0275-- UP---27
0276--CLX---37
0277--XTO---23
0278--IND---31
0279-- a ---13
0280-- 1 ---01
0281--XTO---23
0282-- + ---33
0283-- a ---13
0284-- a ---13
0285--X<Y---52
0286-- 0 ---00
0287-- 2 ---02
0288-- 7 ---07
0289-- 6 ---06
0290--CLR---20
0291--FMT---42
0292-- 1 ---01
0293-- 8 ---10
0294-- 2 ---02
0295--FMT---42
0296--FMT---42
0297--YTO---40
0298--YTO---40
0299-- π ---56
0300--CLR---20
0301--YTO---40
0302-- E ---60
0303-- E ---60
0304--CNT---47
0305-- N ---73
0306-- O ---71
0307--XTO---23
0308-- E ---60
0309--CNT---47
0310-- 1 ---01
0311--FMT---42
0312--STP---41
0313--FMT---42
0314--FMT---42
0315--CNT---47
0316--CLR---20
0317-- N ---73
0318-- a ---13
0319--CNT---47
0320-- π ---56
0321--XTO---23
0322--YTO---40
0323--FMT---42
```

```
0324--STP---41
0325--PNT---45
0326--XTO---23
0327-- 1 ---01
0328-- 0 ---00
0329--CLX---37
0330--XTO---23
0331-- 1 ---01
0332--CNT---47
0333-- 2 ---02
0334-- 8 ---10
0335--XTO---23
0336-- 2 ---02
0337--FMT---42
0338--FMT---42
0339-- D ---63
0340-- E ---60
0341-- π ---56
0342--XTO---23
0343-- H ---74
0344--FMT---42
0345--STP---41
0346--PNT---45
0347-- UP---27
0348--YTO---40
0349--IND---31
0350-- 2 ---02
0351--CNT---47
0352-- . ---21
0353-- 3 ---03
0354-- 0 ---00
0355-- 4 ---04
0356-- 8 ---10
0357-- X ---36
0358--YTO---40
0359-- a ---13
0360-- 1 ---01
0361--XTO---23
0362-- + ---33
0363-- 2 ---02
0364--FMT---42
0365--FMT---42
0366--XTO---23
0367-- E ---60
0368-- M ---70
0369-- π ---56
0370--FMT---42
0371--STP---41
0372--PNT---45
0373--CNT---47
0374-- UP---27
0375-- 3 ---03
0376-- 2 ---02
0377-- - ---34
0378-- 5 ---05
0379-- X ---36
0380-- 9 ---11
0381--DIV---35
0382--YTO---40
0383-- b ---14
0384--FMT---42
0385--FMT---42
0386--YTO---40
0387-- A ---62
0388-- L ---72
0389-- I ---65
0390-- N ---73
0391--FMT---42
0392--STP---41
0393--PNT---45
0394--XTO---23
0395-- 0 ---00
0396--FMT---42
0397--FMT---42
0398--YTO---40
0399-- π ---56
0400-- D ---63
0401--FMT---42
0402--CNT---47
0403--CNT---47
0404-- 3 ---03
0405-- 5 ---05
0406--XTO---23
0407-- - ---34
0408-- 0 ---00
0409--CNT---47
0410-- 1 ---01
0411-- 4 ---04
0412-- 4 ---04
0413-- 9 ---11
0414-- . ---21
0415-- 3 ---03
0416-- UP---27
0417-- a ---13
0418-- UP---27
0419-- 1 ---01
0420-- . ---21
0421-- 5 ---05
0422-- 8 ---10
0423-- 4 ---04
0424-- 8 ---10
0425--EEX---26
0426--CHS---32
0427-- 2 ---02
0428-- X ---36
0429-- DN---25
0430-- + ---33
0431-- b ---14
0432-- UP---27
0433-- 4 ---04
0434-- . ---21
0435-- 5 ---05
0436-- 8 ---10
0437-- 7 ---07
0438-- X ---36
0439-- DN---25
0440-- + ---33
0441--XFR---67
0442-- 0 ---00
0443-- UP---27
0444-- 1 ---01
0445-- . ---21
0446-- 1 ---01
0447-- 9 ---11
0448-- X ---36
0449-- DN---25
0450-- + ---33
0451--XFR---67
0452-- 0 ---00
0453-- UP---27
0454-- b ---14
0455-- X ---36
0456-- 1 ---01
0457-- . ---21
0458-- 2 ---02
0459--EEX---26
0460--CHS---32
0461-- 2 ---02
0462-- X ---36
0463-- DN---25
0464-- - ---34
0465-- a ---13
0466--XSQ---12
0467-- UP---27
0468-- 1 ---01
0469-- . ---21
0470-- 5 ---05
0471-- 7 ---07
0472-- 2 ---02
0473--EEX---26
0474--CHS---32
0475-- 7 ---07
0476-- X ---36
0477-- DN---25
0478-- + ---33
0479-- b ---14
0480-- UP---27
0481-- a ---13
0482--XSQ---12
0483-- X ---36
0484-- 7 ---07
0485-- . ---21
```

```
0486-- 1 ---01
0487-- 9 ---11
0488--EEX---26
0489--CHS---32
0490-- 9 ---11
0491-- X ---36
0492-- DN---25
0493-- - ---34
0494-- b ---14
0495--XSQ---12
0496-- UP---27
0497-- 5 ---05
0498-- . ---21
0499-- 3 ---03
0500-- 5 ---05
0501-- 6 ---06
0502--EEX---26
0503--CHS---32
0504-- 2 ---02
0505-- X ---36
0506-- DN---25
0507-- - ---34
0508-- b ---14
0509--XSQ---12
0510-- UP---27
0511-- a ---13
0512-- X ---36
0513-- 1 ---01
0514-- . ---21
0515-- 3 ---03
0516-- 5 ---05
0517-- 4 ---04
0518--EEX---26
0519--CHS---32
0520-- 6 ---06
0521-- X ---36
0522-- DN---25
0523-- + ---33
0524-- a ---13
0525--XSQ---12
0526-- UP---27
0527-- X ---36
0528-- 3 ---03
0529-- . ---21
0530-- 4 ---04
0531-- 6 ---06
0532--EEX---26
0533--CHS---32
0534-- 1 ---01
0535-- 6 ---06
0536-- X ---36
0537-- DN---25
0538-- - ---34
0539-- b ---14
0540-- UP---27
0541--XSQ---12
0542-- X ---36
0543-- 2 ---02
0544-- . ---21
0545-- 6 ---06
0546-- 0 ---00
0547-- 4 ---04
0548--EEX---26
0549--CHS---32
0550-- 4 ---04
0551-- X ---36
0552-- DN---25
0553-- + ---33
0554--XFR---67
0555-- 0 ---00
0556-- UP---27
0557--XSQ---12
0558-- X ---36
0559-- 9 ---11
0560-- . ---21
0561-- 6 ---06
0562--EEX---26
0563--CHS---32
0564-- 2 ---02
0565-- X ---36
0566-- DN---25
0567-- + ---33
0568-- . ---21
0569-- 3 ---03
0570-- 0 ---00
0571-- 4 ---04
0572-- 8 ---10
0573--DIV---35
0574--YTO---40
0575--IND---31
0576-- 2 ---02
0577-- a ---13
0578--CHS---32
0579-- UP---27
0580-- . ---21
0581-- 3 ---03
0582-- 0 ---00
0583-- 4 ---04
0584-- 8 ---10
0585--DIV---35
0586-- DN---25
0587--XEY---30
0588--PNT---45
0589--PNT---45
0590--FMT---42
0591-- 1 ---01
0592-- DN---25
0593-- 1 ---01
0594--XTO---23
0595-- + ---33
0596-- 2 ---02
0597--XTO---23
0598-- + ---33
0599-- 1 ---01
0600--XFR---67
0601-- 1 ---01
0602-- 0 ---00
0603-- UP---27
0604--XFR---67
0605-- 1 ---01
0606--X<Y---52
0607-- 0 ---00
0608-- 3 ---03
0609-- 3 ---03
0610-- 7 ---07
0611-- K ---55
0612-- 2 ---02
0613--FMT---42
0614-- UP---27
0615-- 2 ---02
0616-- 9 ---11
0617--XTO---23
0618-- a ---13
0619-- 1 ---01
0620-- 8 ---10
0621--XTO---23
0622-- b ---14
0623--XFR---67
0624-- 1 ---01
0625-- 0 ---00
0626-- UP---27
0627-- 2 ---02
0628-- X ---36
0629-- 2 ---02
0630-- 7 ---07
0631-- + ---33
0632--YTO---40
0633-- 0 ---00
0634--CLX---37
0635--XTO---23
0636-- 1 ---01
0637--XTO---23
0638-- 3 ---03
0639--XTO---23
0640-- 2 ---02
0641--GTO---44
0642--S/R---77
0643-- 3 ---03
0644-- 3 ---03
0645--XEY---30
0646-- UP---27
0647-- 1 ---01
```

```
0648--XTO---23
0649-- + ---33
0650-- 1 ---01
0651--XFR---67
0652-- 0 ---00
0653-- UP---27
0654-- a ---13
0655--X>Y---53
0656-- 0 ---00
0657-- 8 ---10
0658-- 3 ---03
0659-- 6 ---06
0660-- DN---25
0661--XFR---67
0662--IND---31
0663-- a ---13
0664--X=Y---50
0665-- 0 ---00
0666-- 8 ---10
0667-- 0 ---00
0668-- 1 ---01
0669--XFR---67
0670-- 3 ---03
0671-- UP---27
0672-- 0 ---00
0673--X=Y---50
0674-- 0 ---00
0675-- 6 ---06
0676-- 9 ---11
0677-- 3 ---03
0678--XTO---23
0679-- 3 ---03
0680-- DN---25
0681--GTO---44
0682--S/R---77
0683-- 3 ---03
0684--XFR---67
0685--IND---31
0686-- a ---13
0687--X<Y---52
0688-- 0 ---00
0689-- 6 ---06
0690-- 9 ---11
0691-- 3 ---03
0692--SFL---54
0693-- DN---25
0694--XFR---67
0695--IND---31
0696-- a ---13
0697--IFG---43
0698-- 0 ---00
0699-- 8 ---10
0700-- 0 ---00
0701-- 9 ---11
```

```
0702--X<Y---52
0703-- 0 ---00
0704-- 7 ---07
0705-- 6 ---06
0706-- 6 ---06
0707-- 1 ---01
0708-- UP---27
0709--XFR---67
0710-- 1 ---01
0711--X>Y---53
0712-- 0 ---00
0713-- 7 ---07
0714-- 5 ---05
0715-- 3 ---03
0716--XFR---67
0717--IND---31
0718-- a ---13
0719--XTO---23
0720--IND---31
0721-- b ---14
0722-- 1 ---01
0723--XTO---23
0724-- - ---34
0725-- a ---13
0726-- 6 ---06
0727--XTO---23
0728-- - ---34
0729-- b ---14
0730--XFR---67
0731--IND---31
0732-- a ---13
0733--XTO---23
0734--IND---31
0735-- b ---14
0736-- 1 ---01
0737--XTO---23
0738-- + ---33
0739-- a ---13
0740-- 6 ---06
0741--XTO---23
0742-- + ---33
0743-- b ---14
0744-- DN---25
0745--XFR---67
0746--IND---31
0747-- a ---13
0748--SFL---54
0749--GTO---44
0750-- 6 ---06
0751-- 4 ---04
0752-- 5 ---05
0753-- DN---25
0754--GTO---44
0755--S/R---77
```

```
0756-- 3 ---03
0757--XFR---67
0758--IND---31
0759-- a ---13
0760--SFL---54
0761--GTO---44
0762-- 6 ---06
0763-- 4 ---04
0764-- 5 ---05
0765--CNT---47
0766-- 1 ---01
0767-- UP---27
0768--XFR---67
0769-- 1 ---01
0770--X>Y---53
0771-- 0 ---00
0772-- 7 ---07
0773-- 7 ---07
0774-- 9 ---11
0775-- DN---25
0776--GTO---44
0777--S/R---77
0778-- 3 ---03
0779-- DN---25
0780--XTO---23
0781-- + ---33
0782-- 1 ---01
0783--XFR---67
0784-- 0 ---00
0785-- UP---27
0786-- a ---13
0787--X>Y---53
0788-- 0 ---00
0789-- 8 ---10
0790-- 3 ---03
0791-- 2 ---02
0792--GTO---44
0793--S/R---77
0794-- 3 ---03
0795-- 3 ---03
0796--GTO---44
0797-- 7 ---07
0798-- 0 ---00
0799-- 2 ---02
0800--CNT---47
0801-- 1 ---01
0802--XTO---23
0803-- + ---33
0804-- 3 ---03
0805--GTO---44
0806-- 6 ---06
0807-- 4 ---04
0808-- 1 ---01
0809--X>Y---53
```

```
0810-- 0 ---00
0811-- 8 ---10
0812-- 2 ---02
0813-- 4 ---04
0814--GTO---44
0815--S/R---77
0816-- 3 ---03
0817--XFR---67
0818--IND---31
0819-- a ---13
0820--GTO---44
0821-- 6 ---06
0822-- 4 ---04
0823-- 5 ---05
0824--GTO---44
0825--S/R---77
0826-- 3 ---03
0827-- 3 ---03
0828--GTO---44
0829-- 8 ---10
0830-- 0 ---00
0831-- 9 ---11
0832-- DN---25
0833--GTO---44
0834--S/R---77
0835-- 3 ---03
0836--XFR---67
0837-- 2 ---02
0838-- 8 ---10
0839--XTO---23
0840-- 1 ---01
0841-- 1 ---01
0842--XFR---67
0843-- 2 ---02
0844-- 9 ---11
0845--XTO---23
0846-- 1 ---01
0847-- 7 ---07
0848--XFR---67
0849--IND---31
0850-- 0 ---00
0851--XTO---23
0852-- 0 ---00
0853-- 2 ---02
0854-- 2 ---02
0855-- 1 ---01
0856--XTO---23
0857-- - ---34
0858-- 0 ---00
0859--XFR---67
0860--IND---31
0861-- 0 ---00
0862--XTO---23
0863-- 1 ---01
0864-- 6 ---06
0865--XFR---67
0866-- 2 ---02
0867--XTO---23
0868-- 5 ---05
0869-- 8 ---10
0870--LBL---51
0871-- B ---66
0872--FMT---42
0873--FMT---42
0874--YTO---40
0875-- E ---60
0876-- E ---60
0877--CNT---47
0878-- N ---73
0879-- O ---71
0880--XTO---23
0881-- E ---60
0882--CNT---47
0883-- 2 ---02
0884--FMT---42
0885--STP---41
0886--GTO---44
0887-- 1 ---01
0888-- 1 ---01
0889-- 6 ---06
0890-- 0 ---00
0891--XFR---67
0892-- 6 ---06
0893-- 0 ---00
0894-- UP---27
0895-- 1 ---01
0896--X=Y---50
0897--XTO---23
0898-- 5 ---05
0899-- 9 ---11
0900--CNT---47
0901--XFR---67
0902-- 1 ---01
0903-- 0 ---00
0904-- UP---27
0905-- 2 ---02
0906-- X ---36
0907-- 2 ---02
0908-- 6 ---06
0909-- + ---33
0910--YTO---40
0911-- a ---13
0912--XFR---67
0913-- 6 ---06
0914-- 4 ---04
0915--XTO---23
0916-- 7 ---07
0917-- 4 ---04
0918--XFR---67
0919-- 4 ---04
0920--XTO---23
0921-- 7 ---07
0922-- 2 ---02
0923--CHS---32
0924-- UP---27
0925--CLX---37
0926--XTO---23
0927-- 7 ---07
0928-- 1 ---01
0929--FMT---42
0930-- 1 ---01
0931-- UP---27
0932-- 2 ---02
0933-- 6 ---06
0934--XTO---23
0935-- b ---14
0936-- 2 ---02
0937--XTO---23
0938-- + ---33
0939-- b ---14
0940--XFR---67
0941-- 7 ---07
0942-- 2 ---02
0943-- UP---27
0944--XFR---67
0945--IND---31
0946-- b ---14
0947--X>Y---53
0948-- 0 ---00
0949-- 9 ---11
0950-- 6 ---06
0951-- 4 ---04
0952-- a ---13
0953-- UP---27
0954-- b ---14
0955--X=Y---50
0956--CNT---47
0957--S/R---77
0958--CNT---47
0959--CNT---47
0960--GTO---44
0961-- 9 ---11
0962-- 3 ---03
0963-- 6 ---06
0964--XTO---23
0965-- 3 ---03
0966--CLX---37
0967-- 2 ---02
0968--XTO---23
0969-- - ---34
0970-- b ---14
0971--CLX---37
```

```
0972-- UP---27
0973--XFR---67
0974-- 7 ---07
0975-- 2 ---02
0976--X<Y---52
0977--CNT---47
0978--S/R---77
0979--CNT---47
0980--CNT---47
0981--XFR---67
0982--IND---31
0983-- b ---14
0984--XTO---23
0985-- 2 ---02
0986--CLX---37
0987-- 1 ---01
0988--XTO---23
0989-- + ---33
0990-- b ---14
0991--XFR---67
0992--IND---31
0993-- b ---14
0994--XTO---23
0995-- 1 ---01
0996-- UP---27
0997-- 2 ---02
0998--XTO---23
0999-- + ---33
1000-- b ---14
1001--XFR---67
1002--IND---31
1003-- b ---14
1004--XTO---23
1005-- 0 ---00
1006-- - ---34
1007-- 1 ---01
1008--XTO---23
1009-- - ---34
1010-- b ---14
1011--XFR---67
1012-- 2 ---02
1013-- UP---27
1014--XFR---67
1015-- 3 ---03
1016-- - ---34
1017-- DN---25
1018--DIV---35
1019--YTO---40
1020-- 7 ---07
1021-- 3 ---03
1022--XFR---67
1023-- 7 ---07
1024-- 4 ---04
1025--XSQ---12
```

```
1026-- UP---27
1027-- 2 ---02
1028--DIV---35
1029-- 1 ---01
1030--XEY---30
1031-- - ---34
1032-- DN---25
1033--CHS---32
1034-- X ---36
1035--RUP---22
1036--XEY---30
1037--XFR---67
1038-- 7 ---07
1039-- 2 ---02
1040--XFR---67
1041-- - ---34
1042-- 2 ---02
1043-- X ---36
1044-- DN---25
1045--XFR---67
1046-- + ---33
1047-- 1 ---01
1048--DIV---35
1049--YTO---40
1050-- 6 ---06
1051-- 9 ---11
1052--XFR---67
1053-- 3 ---03
1054--XFR---67
1055-- - ---34
1056-- 2 ---02
1057-- √ ---76
1058-- UP---27
1059-- 5 ---05
1060-- X ---36
1061-- DN---25
1062--XTO---23
1063-- 7 ---07
1064-- 5 ---05
1065--XFR---67
1066-- 6 ---06
1067-- 9 ---11
1068-- UP---27
1069--XFR---67
1070-- 7 ---07
1071-- 5 ---05
1072-- X ---36
1073--YTO---40
1074-- 6 ---06
1075-- 1 ---01
1076--XTO---23
1077-- + ---33
1078-- 7 ---07
1079-- 1 ---01
```

```
1080-- X ---36
1081-- UP---27
1082--XFR---67
1083-- 7 ---07
1084-- 4 ---04
1085-- X ---36
1086--RUP---22
1087--XEY---30
1088-- 2 ---02
1089--DIV---35
1090-- DN---25
1091-- + ---33
1092--YTO---40
1093-- + ---33
1094-- 7 ---07
1095-- 2 ---02
1096--XFR---67
1097-- 6 ---06
1098-- 1 ---01
1099--XTO---23
1100-- + ---33
1101-- 7 ---07
1102-- 4 ---04
1103--XFR---67
1104-- 5 ---05
1105-- 9 ---11
1106-- UP---27
1107--CLX---37
1108--X<Y---52
1109-- 1 ---01
1110-- 1 ---01
1111-- 2 ---02
1112-- 4 ---04
1113--XFR---67
1114-- 7 ---07
1115-- 2 ---02
1116--CHS---32
1117-- UP---27
1118--XFR---67
1119-- 7 ---07
1120-- 1 ---01
1121--FMT---42
1122-- 1 ---01
1123-- DN---25
1124--XFR---67
1125-- 2 ---02
1126-- UP---27
1127--XFR---67
1128-- 7 ---07
1129-- 2 ---02
1130--X<Y---52
1131-- 0 ---00
1132-- 9 ---11
1133-- 3 ---03
```

```
1134-- 2 ---02
1135-- UP---27
1136--XFR---67
1137-- 3 ---03
1138--X<Y---52
1139-- 0 ---00
1140-- 9 ---11
1141-- 3 ---03
1142-- 2 ---02
1143--XFR---67
1144-- 7 ---07
1145-- 1 ---01
1146-- UP---27
1147-- 3 ---03
1148--EEX---26
1149-- 5 ---05
1150--X<Y---52
1151--CNT---47
1152--S/R---77
1153--CNT---47
1154--CNT---47
1155--GTO---44
1156-- 1 ---01
1157-- 0 ---00
1158-- 6 ---06
1159-- 5 ---05
1160--XTO---23
1161-- 6 ---06
1162-- 0 ---00
1163-- π ---56
1164-- UP---27
1165-- 3 ---03
1166-- 6 ---06
1167-- 0 ---00
1168--DIV---35
1169--YTO---40
1170-- 6 ---06
1171-- 3 ---03
1172--YTO---40
1173-- a ---13
1174-- 5 ---05
1175--CNT---47
1176--DIV---35
1177--YTO---40
1178-- 6 ---06
1179-- 2 ---02
1180--FMT---42
1181--FMT---42
1182-- a ---13
1183-- A ---62
1184--XFR---67
1185--CLR---20
1186--YTO---40
1187-- O ---71
1188--1/X---17
1189-- a ---13
1190-- C ---61
1191-- E ---60
1192--CNT---47
1193-- D ---63
1194-- E ---60
1195-- π ---56
1196--XTO---23
1197-- H ---74
1198--FMT---42
1199--STP---41
1200--PNT---45
1201--XTO---23
1202-- 4 ---04
1203--XTO---23
1204-- 7 ---07
1205-- 2 ---02
1206--XFR---67
1207-- 6 ---06
1208-- 0 ---00
1209-- UP---27
1210--CLX---37
1211--X=Y---50
1212-- 1 ---01
1213-- 3 ---03
1214-- 1 ---01
1215-- 6 ---06
1216-- 1 ---01
1217--X=Y---50
1218-- 1 ---01
1219-- 5 ---05
1220-- 3 ---03
1221-- 3 ---03
1222--GTO---44
1223-- 1 ---01
1224-- 2 ---02
1225-- 4 ---04
1226-- 7 ---07
1227--FMT---42
1228--FMT---42
1229-- N ---73
1230-- O ---71
1231--CNT---47
1232-- C ---61
1233--XSQ---12
1234--FMT---42
1235--GTO---44
1236--S/R---77
1237-- 1 ---01
1238-- 6 ---06
1239-- 0 ---00
1240-- 1 ---01
1241--SFL---54
1242--GTO---44
1243-- 1 ---01
1244-- 9 ---11
1245-- 5 ---05
1246-- 1 ---01
1247--FMT---42
1248--FMT---42
1249-- M ---70
1250-- I ---65
1251-- N ---73
1252--CNT---47
1253-- a ---13
1254-- A ---62
1255--XFR---67
1256--CNT---47
1257-- A ---62
1258-- N ---73
1259-- G ---15
1260--FMT---42
1261--STP---41
1262--PNT---45
1263--XFR---67
1264-- X ---36
1265-- a ---13
1266--XTO---23
1267-- 6 ---06
1268-- 4 ---04
1269--XTO---23
1270-- 7 ---07
1271-- 4 ---04
1272--FMT---42
1273--FMT---42
1274-- a ---13
1275-- A ---62
1276--XFR---67
1277--CNT---47
1278-- A ---62
1279-- N ---73
1280-- G ---15
1281--CNT---47
1282-- I ---65
1283-- N ---73
1284-- C ---61
1285--FMT---42
1286--STP---41
1287--PNT---45
1288--XFR---67
1289-- X ---36
1290-- a ---13
1291--XTO---23
1292-- 6 ---06
1293-- 5 ---05
1294--FMT---42
1295--FMT---42
```

```
1296-- M ---70
1297-- A ---62
1298-- YE---24
1299--CNT---47
1300-- a ---13
1301-- A ---62
1302--XFR---67
1303--CNT---47
1304-- A ---62
1305-- N ---73
1306-- G ---15
1307--FMT---42
1308--STP---41
1309--PNT---45
1310--XFR---67
1311-- X ---36
1312-- a ---13
1313--XTO---23
1314-- 6 ---06
1315-- 6 ---06
1316--FMT---42
1317-- 1 ---01
1318-- 8 ---10
1319-- 0 ---00
1320--CLX---37
1321-- 3 ---03
1322--EEX---26
1323-- 5 ---05
1324-- UP---27
1325--CHS---32
1326-- 5 ---05
1327--EEX---26
1328-- 4 ---04
1329--FMT---42
1330-- 1 ---01
1331-- 2 ---02
1332-- 2 ---02
1333-- 5 ---05
1334-- 0 ---00
1335-- 0 ---00
1336-- UP---27
1337--CHS---32
1338-- 2 ---02
1339--EEX---26
1340-- 4 ---04
1341--FMT---42
1342-- 1 ---01
1343-- 3 ---03
1344--CLX---37
1345-- UP---27
1346--FMT---42
1347-- 1 ---01
1348-- UP---27
1349-- 3 ---03
1350--EEX---26
1351-- 4 ---04
1352--FMT---42
1353-- 1 ---01
1354-- 5 ---05
1355-- 5 ---05
1356-- 0 ---00
1357-- 0 ---00
1358--FMT---42
1359-- 1 ---01
1360-- 6 ---06
1361-- . ---21
1362-- 1 ---01
1363-- 0 ---00
1364--FMT---42
1365-- 1 ---01
1366-- 1 ---01
1367-- 1 ---01
1368-- 2 ---02
1369-- 7 ---07
1370-- 5 ---05
1371-- UP---27
1372-- 1 ---01
1373-- 2 ---02
1374--EEX---26
1375-- 4 ---04
1376--FMT---42
1377-- 1 ---01
1378-- UP---27
1379--FMT---42
1380-- 1 ---01
1381--FMT---42
1382-- a ---13
1383-- A ---62
1384-- N ---73
1385-- G ---15
1386-- E ---60
1387--CNT---47
1388--X<Y---52
1389-- N ---73
1390-- M ---70
1391--PSE---57
1392--FMT---42
1393-- 5 ---05
1394-- 5 ---05
1395-- 5 ---05
1396--EEX---26
1397-- 2 ---02
1398--XTO---23
1399-- a ---13
1400-- 1 ---01
1401-- 0 ---00
1402--XTO---23
1403-- b ---14
1404-- 3 ---03
1405-- 0 ---00
1406-- 0 ---00
1407-- UP---27
1408-- a ---13
1409--FMT---42
1410-- 1 ---01
1411-- UP---27
1412-- b ---14
1413--FMT---42
1414-- 1 ---01
1415--PNT---45
1416-- 6 ---06
1417--EEX---26
1418-- 4 ---04
1419--XTO---23
1420-- + ---33
1421-- a ---13
1422-- 1 ---01
1423-- 0 ---00
1424--XTO---23
1425-- + ---33
1426-- b ---14
1427-- b ---14
1428-- UP---27
1429-- 5 ---05
1430-- 0 ---00
1431--X>Y---53
1432-- 1 ---01
1433-- 4 ---04
1434-- 0 ---00
1435-- 4 ---04
1436--FMT---42
1437-- 1 ---01
1438-- 9 ---11
1439--CHS---32
1440-- 1 ---01
1441-- 2 ---02
1442--EEX---26
1443-- 3 ---03
1444-- UP---27
1445--CHS---32
1446-- 3 ---03
1447-- 5 ---05
1448--EEX---26
1449-- 3 ---03
1450--FMT---42
1451-- 1 ---01
1452-- UP---27
1453--FMT---42
1454-- 1 ---01
1455--FMT---42
1456-- D ---63
1457-- E ---60
```

```
1458-- π ---56
1459--XTO---23
1460-- H ---74
1461--CNT---47
1462--X<Y---52
1463-- F ---16
1464--XTO---23
1465--CNT---47
1466-- YE---24
1467--CNT---47
1468-- 1 ---01
1469-- 0 ---00
1470-- 0 ---00
1471--PSE---57
1472--FMT---42
1473--FMT---42
1474-- 1 ---01
1475-- 9 ---11
1476-- 2 ---02
1477-- 6 ---06
1478-- 0 ---00
1479-- 0 ---00
1480--CHS---32
1481--XTO---23
1482-- a ---13
1483-- 2 ---02
1484-- 5 ---05
1485--XTO---23
1486-- b ---14
1487-- a ---13
1488-- UP---27
1489--CHS---32
1490-- 2 ---02
1491-- 5 ---05
1492--EEX---26
1493-- 3 ---03
1494--FMT---42
1495-- 1 ---01
1496-- UP---27
1497-- b ---14
1498--FMT---42
1499-- 1 ---01
1500--PNT---45
1501-- 2 ---02
1502-- 5 ---05
1503-- 0 ---00
1504-- 0 ---00
1505--XTO---23
1506-- - ---34
1507-- a ---13
1508-- 2 ---02
1509-- 5 ---05
1510--XTO---23
1511-- + ---33
1512-- b ---14
1513-- b ---14
1514-- UP---27
1515-- 2 ---02
1516--EEX---26
1517-- 2 ---02
1518--X>Y---53
1519-- 1 ---01
1520-- 4 ---04
1521-- 8 ---10
1522-- 7 ---07
1523-- 2 ---02
1524-- UP---27
1525--XFR---67
1526-- 6 ---06
1527-- 0 ---00
1528--X=Y---50
1529-- 1 ---01
1530-- 9 ---11
1531-- 5 ---05
1532-- 1 ---01
1533--XFR---67
1534-- 1 ---01
1535-- 8 ---10
1536-- UP---27
1537--XFR---67
1538-- 2 ---02
1539-- 2 ---02
1540--X>Y---53
1541-- 1 ---01
1542-- 5 ---05
1543-- 5 ---05
1544-- 0 ---00
1545--GTO---44
1546-- 1 ---01
1547-- 2 ---02
1548-- 2 ---02
1549-- 7 ---07
1550-- 1 ---01
1551-- 8 ---10
1552--XTO---23
1553-- a ---13
1554-- 1 ---01
1555--XTO---23
1556-- + ---33
1557-- a ---13
1558--XFR---67
1559--IND---31
1560-- a ---13
1561-- UP---27
1562--CLX---37
1563--X=Y---50
1564-- 1 ---01
1565-- 2 ---02
1566-- 2 ---02
1567-- 7 ---07
1568--XFR---67
1569-- 1 ---01
1570-- 8 ---10
1571--X>Y---53
1572-- 1 ---01
1573-- 5 ---05
1574-- 9 ---11
1575-- 0 ---00
1576-- a ---13
1577-- UP---27
1578-- 2 ---02
1579-- 1 ---01
1580--X=Y---50
1581-- 1 ---01
1582-- 2 ---02
1583-- 2 ---02
1584-- 7 ---07
1585--GTO---44
1586-- 1 ---01
1587-- 5 ---05
1588-- 5 ---05
1589-- 4 ---04
1590--GTO---44
1591--S/R---77
1592-- 1 ---01
1593-- 6 ---06
1594-- 0 ---00
1595-- 1 ---01
1596--GTO---44
1597-- 1 ---01
1598-- 7 ---07
1599-- 0 ---00
1600-- 7 ---07
1601--CNT---47
1602-- 2 ---02
1603-- 6 ---06
1604--XTO---23
1605-- a ---13
1606-- 2 ---02
1607--XTO---23
1608-- + ---33
1609-- a ---13
1610--XFR---67
1611--IND---31
1612-- a ---13
1613-- UP---27
1614--XFR---67
1615-- 4 ---04
1616--X<Y---52
1617-- 1 ---01
1618-- 6 ---06
1619-- 2 ---02
```

```
1620-- 6 ---06
1621--GTO---44
1622-- 1 ---01
1623-- 6 ---06
1624-- 0 ---00
1625-- 6 ---06
1626--XFR---67
1627--IND---31
1628-- a ---13
1629-- UP---27
1630-- 2 ---02
1631--XTO---23
1632-- - ---34
1633-- a ---13
1634--XFR---67
1635--IND---31
1636-- a ---13
1637-- - ---34
1638-- UP---27
1639--XFR---67
1640-- 4 ---04
1641--XEY---30
1642-- - ---34
1643--YTO---40
1644-- 3 ---03
1645-- DN---25
1646-- 1 ---01
1647--XTO---23
1648-- + ---33
1649-- a ---13
1650--XFR---67
1651--IND---31
1652-- a ---13
1653-- UP---27
1654-- 2 ---02
1655--XTO---23
1656-- + ---33
1657-- a ---13
1658--XFR---67
1659--IND---31
1660-- a ---13
1661--XEY---30
1662-- - ---34
1663--RUP---22
1664--RUP---22
1665--XEY---30
1666--DIV---35
1667--XFR---67
1668-- 3 ---03
1669-- X ---36
1670-- DN---25
1671-- + ---33
1672--YTO---40
1673-- 5 ---05
1674--XFR---67
1675-- 1 ---01
1676-- 8 ---10
1677-- UP---27
1678-- DN---25
1679--DIV---35
1680-- 2 ---02
1681--CHS---32
1682-- X ---36
1683--CHS---32
1684-- + ---33
1685-- DN---25
1686-- r ---76
1687--XTO---23
1688-- 6 ---06
1689-- 8 ---10
1690--XFR---67
1691-- 2 ---02
1692-- 2 ---02
1693--DIV---35
1694-- 2 ---02
1695--CHS---32
1696-- X ---36
1697--CHS---32
1698-- + ---33
1699-- G ---15
1700-- DN---25
1701-- r ---76
1702--XTO---23
1703-- 6 ---06
1704-- 7 ---07
1705--CNT---47
1706--S/R---77
1707--XFR---67
1708-- 6 ---06
1709-- 0 ---00
1710-- UP---27
1711-- 2 ---02
1712--X=Y---50
1713-- 1 ---01
1714-- 9 ---11
1715-- 5 ---05
1716-- 1 ---01
1717--XFR---67
1718-- 6 ---06
1719-- 7 ---07
1720--XTO---23
1721-- 6 ---06
1722-- 4 ---04
1723--GTO---44
1724--S/R---77
1725-- 8 ---10
1726-- 9 ---11
1727-- 1 ---01
1728--XFR---67
1729-- 7 ---07
1730-- 2 ---02
1731-- UP---27
1732--XFR---67
1733--IND---31
1734-- a ---13
1735--X<Y---52
1736-- 1 ---01
1737-- 7 ---07
1738-- 6 ---06
1739-- 1 ---01
1740--IFG---43
1741-- 1 ---01
1742-- 7 ---07
1743-- 7 ---07
1744-- 8 ---10
1745--CLX---37
1746--XTO---23
1747-- 5 ---05
1748-- 9 ---11
1749--XFR---67
1750-- 6 ---06
1751-- 3 ---03
1752--XTO---23
1753-- + ---33
1754-- 6 ---06
1755-- 4 ---04
1756--GTO---44
1757-- 1 ---01
1758-- 7 ---07
1759-- 2 ---02
1760-- 3 ---03
1761-- 1 ---01
1762--XTO---23
1763-- 5 ---05
1764-- 9 ---11
1765--XFR---67
1766-- 6 ---06
1767-- 2 ---02
1768--XTO---23
1769-- - ---34
1770-- 6 ---06
1771-- 4 ---04
1772--SFL---54
1773--GTO---44
1774-- 1 ---01
1775-- 7 ---07
1776-- 2 ---02
1777-- 3 ---03
1778--XFR---67
1779-- 6 ---06
1780-- 4 ---04
1781--XTO---23
```

```
1782-- 7 ---07
1783--XFR---67
1784-- 7 ---07
1785-- 1 ---01
1786--XTO---23
1787-- 9 ---11
1788-- UP---27
1789-- 1 ---01
1790--XTO---23
1791-- 2 ---02
1792-- 6 ---06
1793--CLX---37
1794--XTO---23
1795-- 5 ---05
1796-- 9 ---11
1797--GTO---44
1798--S/R---77
1799-- 8 ---10
1800-- 9 ---11
1801-- 1 ---01
1802--XFR---67
1803-- 6 ---06
1804-- 8 ---10
1805--XTO---23
1806-- 6 ---06
1807-- 4 ---04
1808--GTO---44
1809--S/R---77
1810-- 8 ---10
1811-- 9 ---11
1812-- 1 ---01
1813--XFR---67
1814-- 9 ---11
1815-- UP---27
1816-- 2 ---02
1817--DIV---35
1818--XFR---67
1819-- 7 ---07
1820-- 1 ---01
1821--X>Y---53
1822-- 1 ---01
1823-- 8 ---10
1824-- 4 ---04
1825-- 8 ---10
1826--XFR---67
1827-- 6 ---06
1828-- 2 ---02
1829--XTO---23
1830-- + ---33
1831-- 6 ---06
1832-- 4 ---04
1833--CNT---47
1834-- 1 ---01
1835--XTO---23
```

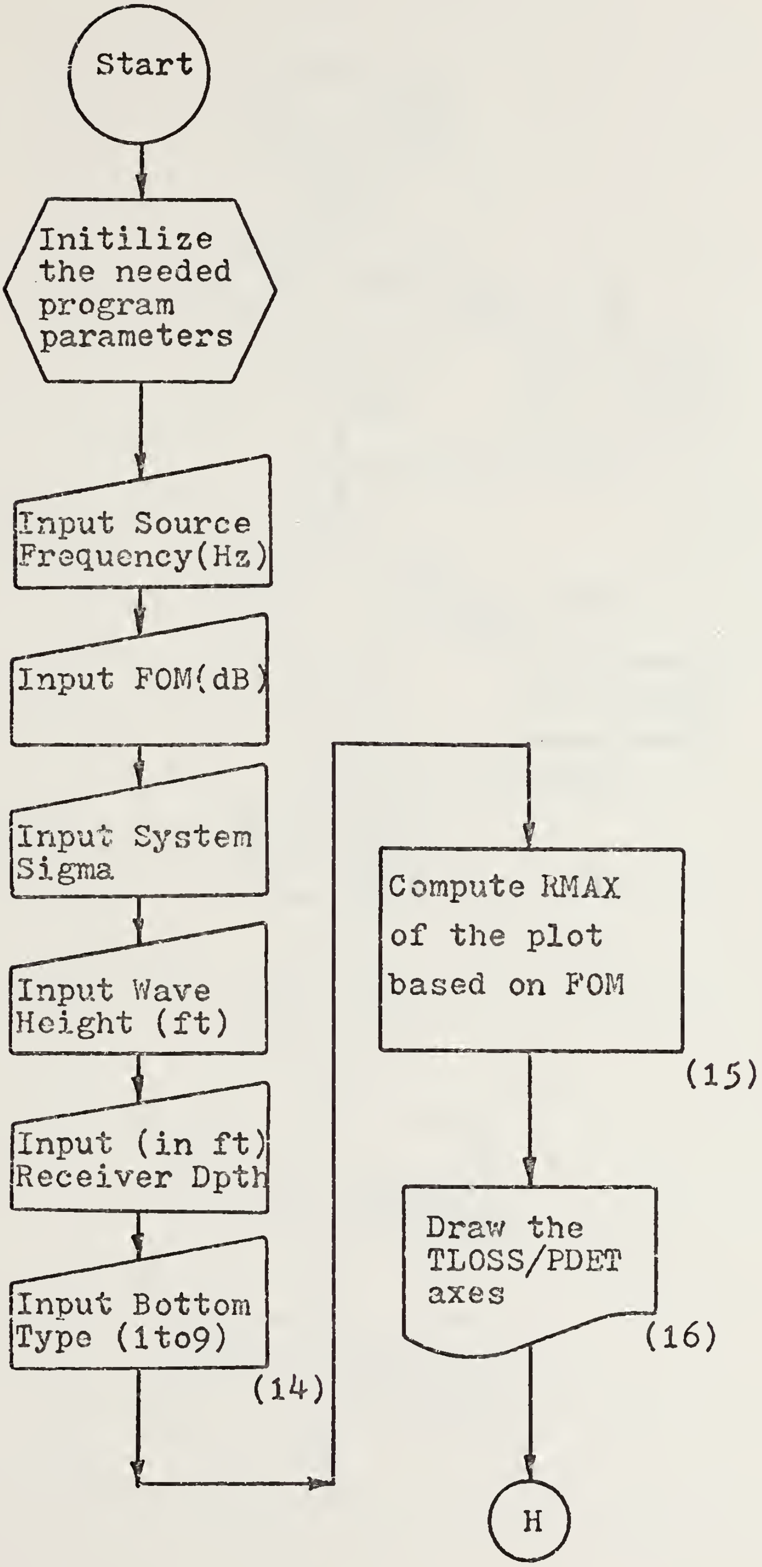
```
1836-- 5 ---05
1837-- 9 ---11
1838--GTO---44
1839--S/R---77
1840-- 8 ---10
1841-- 9 ---11
1842-- 1 ---01
1843--GTO---44
1844-- 1 ---01
1845-- 8 ---10
1846-- 1 ---01
1847-- 3 ---03
1848--XFR---67
1849-- 9 ---11
1850-- UP---27
1851--XFR---67
1852-- 7 ---07
1853-- 1 ---01
1854--X>Y---53
1855--XTO---23
1856-- 9 ---11
1857--CNT---47
1858--CNT---47
1859--XTO---23
1860-- 8 ---10
1861--XFR---67
1862-- 6 ---06
1863-- 3 ---03
1864--XTO---23
1865-- + ---33
1866-- 6 ---06
1867-- 4 ---04
1868--CLX---37
1869--XTO---23
1870-- 5 ---05
1871-- 9 ---11
1872--GTO---44
1873--S/R---77
1874-- 8 ---10
1875-- 9 ---11
1876-- 1 ---01
1877--XFR---67
1878-- 8 ---10
1879-- UP---27
1880--XFR---67
1881-- 7 ---07
1882-- 1 ---01
1883--X<Y---52
1884-- 1 ---01
1885-- 8 ---10
1886-- 5 ---05
1887-- 9 ---11
1888--XFR---67
1889-- 6 ---06
```

```
1890-- 3 ---03
1891--XTO---23
1892-- - ---34
1893-- 6 ---06
1894-- 4 ---04
1895--XFR---67
1896-- 6 ---06
1897-- 2 ---02
1898--XTO---23
1899-- + ---33
1900-- 6 ---06
1901-- 4 ---04
1902--CNT---47
1903-- 1 ---01
1904--XTO---23
1905-- 5 ---05
1906-- 9 ---11
1907--GTO---44
1908--S/R---77
1909-- 8 ---10
1910-- 9 ---11
1911-- 1 ---01
1912--XFR---67
1913-- 8 ---10
1914-- UP---27
1915--XFR---67
1916-- 7 ---07
1917-- 1 ---01
1918--X>Y---53
1919-- 1 ---01
1920-- 9 ---11
1921-- 3 ---03
1922-- 0 ---00
1923--XTO---23
1924-- 8 ---10
1925--GTO---44
1926-- 1 ---01
1927-- 8 ---10
1928-- 9 ---11
1929-- 5 ---05
1930--CLX---37
1931--XTO---23
1932-- 5 ---05
1933-- 9 ---11
1934--XFR---67
1935-- 6 ---06
1936-- 2 ---02
1937--XTO---23
1938-- - ---34
1939-- 6 ---06
1940-- 4 ---04
1941--GTO---44
1942--S/R---77
1943-- 8 ---10
```

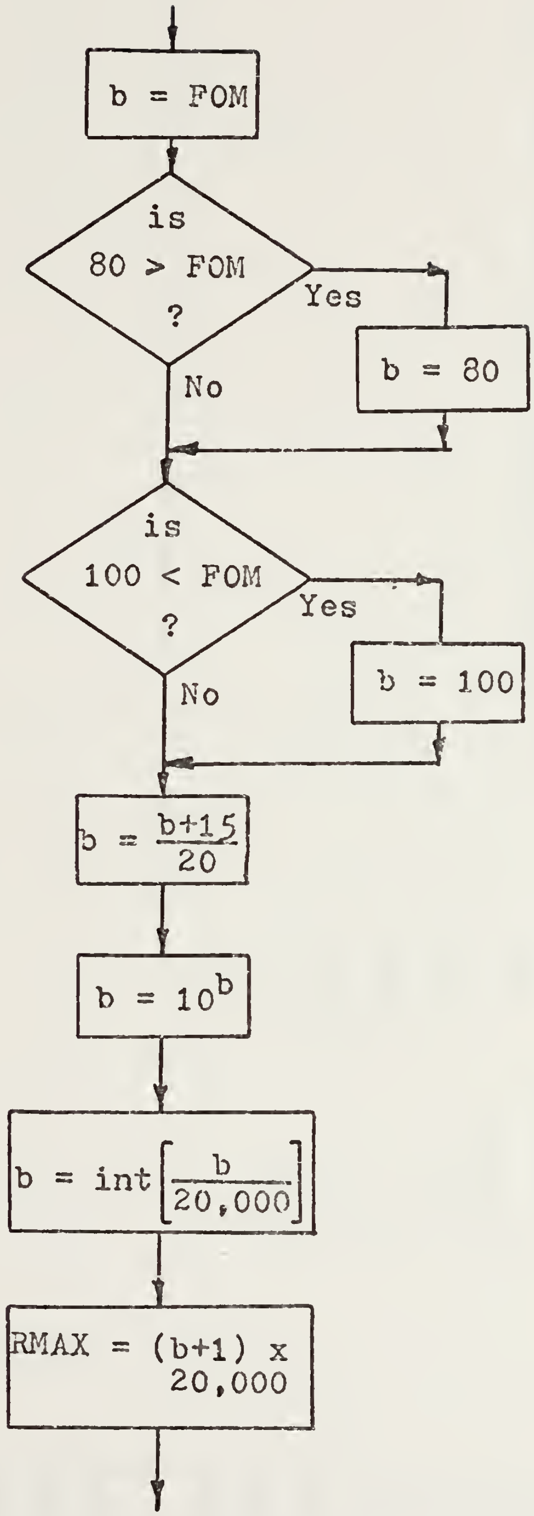
```
1944-- 9 ---11
1945-- 1 ---01
1946--GTO---44
1947-- 1 ---01
1948-- 9 ---11
1949-- 9 ---11
1950-- 4 ---04
1951--IFG---43
1952-- 1 ---01
1953-- 9 ---11
1954-- 9 ---11
1955-- 4 ---04
1956--GTO---44
1957--S/R---77
1958-- 8 ---10
1959-- 9 ---11
1960-- 1 ---01
1961--XFR---67
1962-- 6 ---06
1963-- 6 ---06
1964-- UP---27
1965--XFR---67
1966-- 6 ---06
1967-- 4 ---04
1968--XFR---67
1969-- + ---33
1970-- 6 ---06
1971-- 5 ---05
1972--XTO---23
1973-- 6 ---06
1974-- 4 ---04
1975--X>Y---53
1976-- 1 ---01
1977-- 9 ---11
1978-- 8 ---10
1979-- 5 ---05
1980--GTO---44
1981-- 1 ---01
1982-- 9 ---11
1983-- 5 ---05
1984-- 1 ---01
1985-- 1 ---01
1986--XTO---23
1987-- 6 ---06
1988-- 0 ---00
1989--GTO---44
1990-- 1 ---01
1991-- 5 ---05
1992-- 3 ---03
1993-- 3 ---03
1994-- 1 ---01
1995--XTO---23
1996-- 2 ---02
1997-- 4 ---04
1998--CLX---37
1999-- UP---27
2000-- 3 ---03
2001--EEX---26
2002-- 5 ---05
2003--FMT---42
2004-- 1 ---01
2005-- UP---27
2006-- 3 ---03
2007--XTO---23
2008--DIV---35
2009-- 8 ---10
2010--XTO---23
2011--DIV---35
2012-- 9 ---11
2013--CLX---37
2014--XTO---23
2015-- 5 ---05
2016-- 9 ---11
2017--FMT---42
2018--FMT---42
2019--YTO---40
2020-- E ---60
2021-- E ---60
2022--CNT---47
2023-- N ---73
2024-- O ---71
2025--XTO---23
2026-- E ---60
2027--CNT---47
2028-- 3 ---03
2029--CLR---20
2030-- E ---60
2031-- N ---73
2032-- D ---63
2033--FMT---42
2034--END---46
```

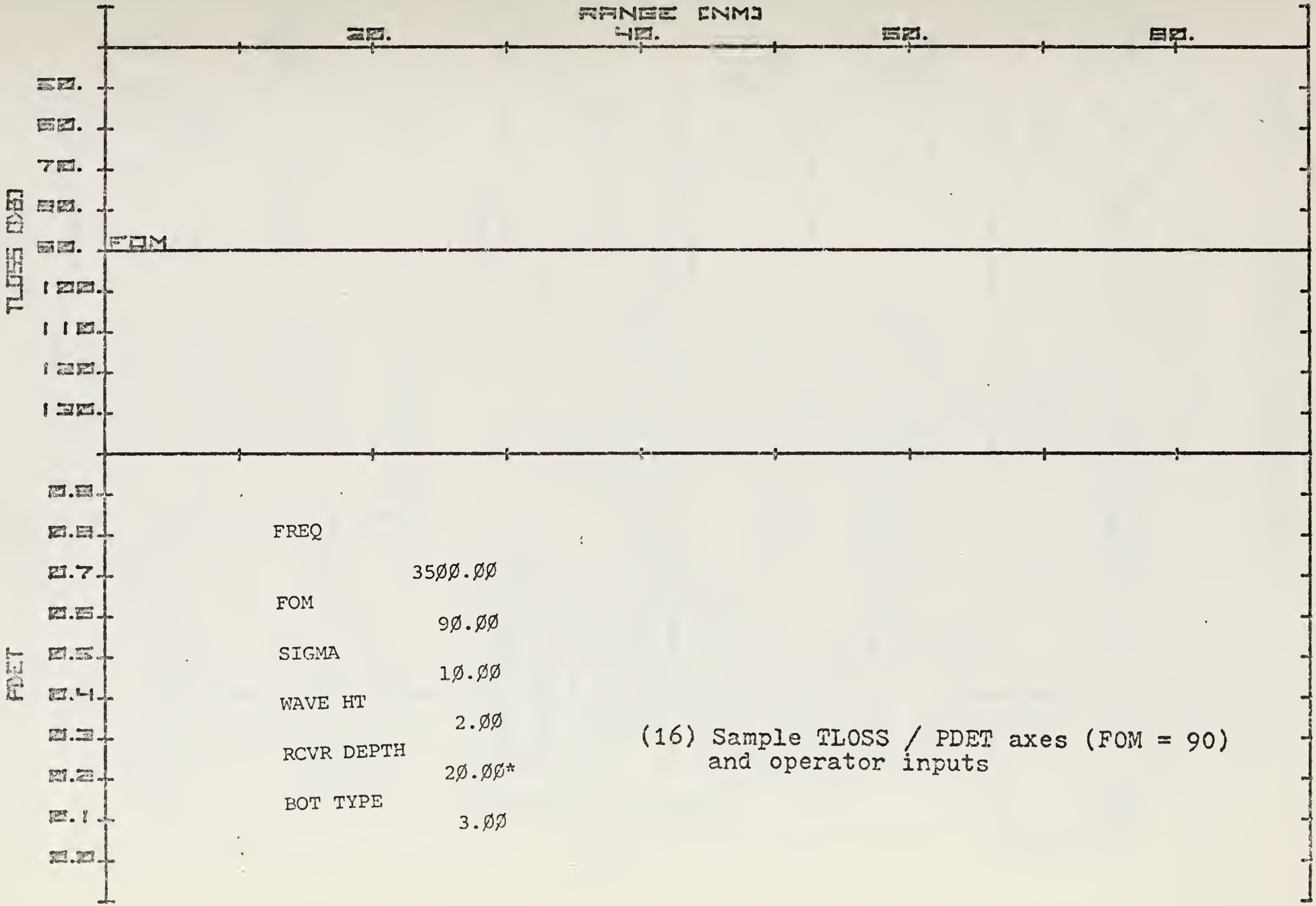
Transmission Loss / Probability of Detection Program flow charts and sample outputs

TLOSS / PDET Program


Start
Initilize the needed program parameters
Input Source Frequency(Hz)
Input FOM(dB)
Input System Sigma
Input Wave Height (ft)
Input (in ft) Receiver Dpth
Input Bottom Type (1to9)
(14)
Compute RMAX of the plot based on FOM
(15)
Draw the TLOSS/PDET axes
(16)
H

(15) RMAX Determination





FREQ 3500.00

FOM 90.00

SIGMA 10.00

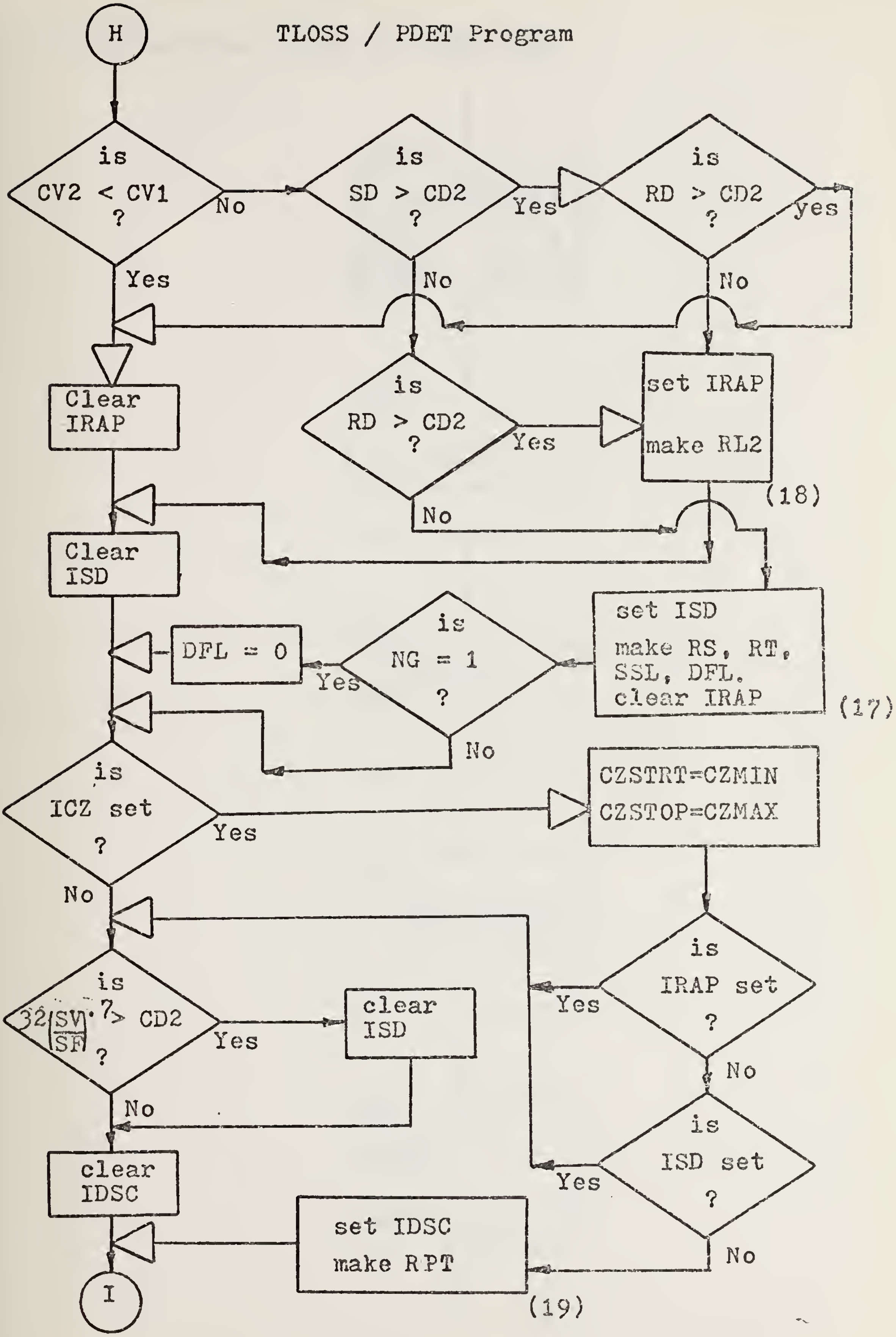
WAVE HT 2.00

RCVR DEPTH 20.00*

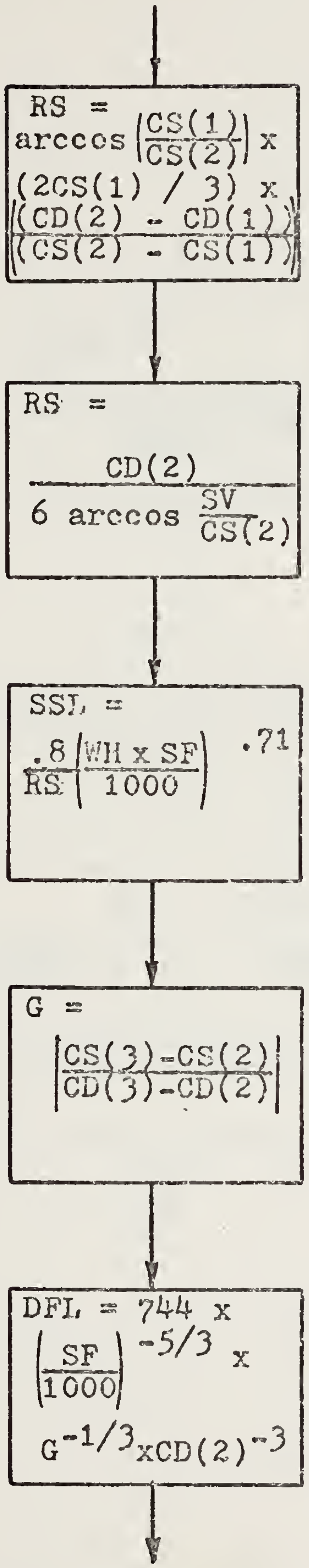
BOT TYPE 3.00

(16) Sample TLOSS / PDET axes (FOM = 90) and operator inputs

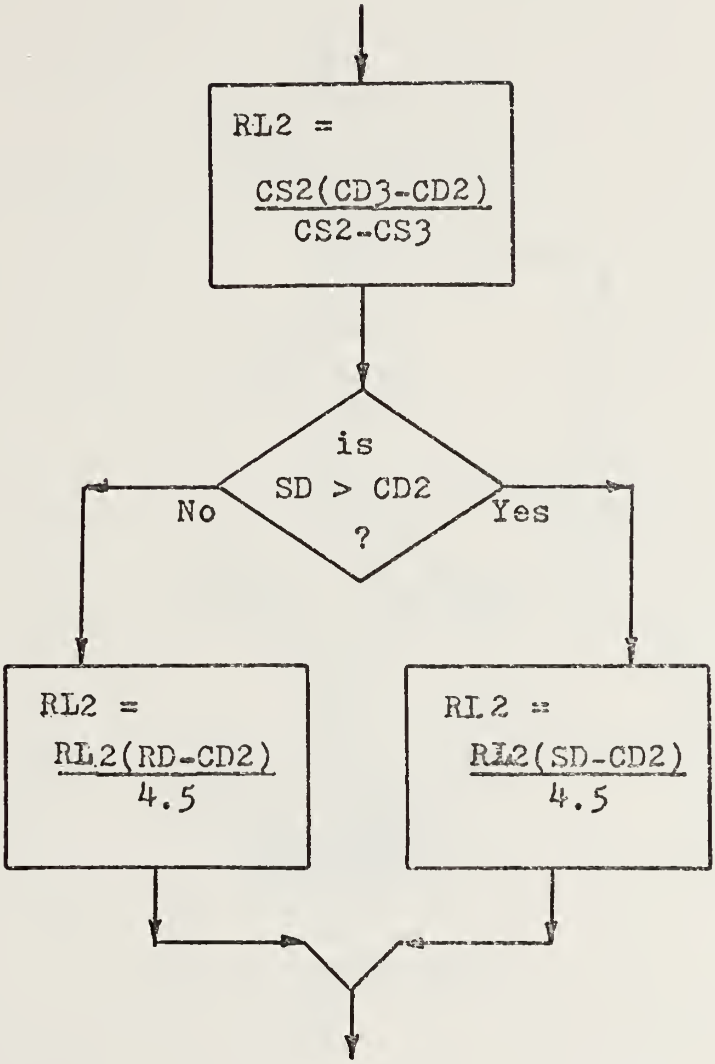
TLOSS / PDET Program



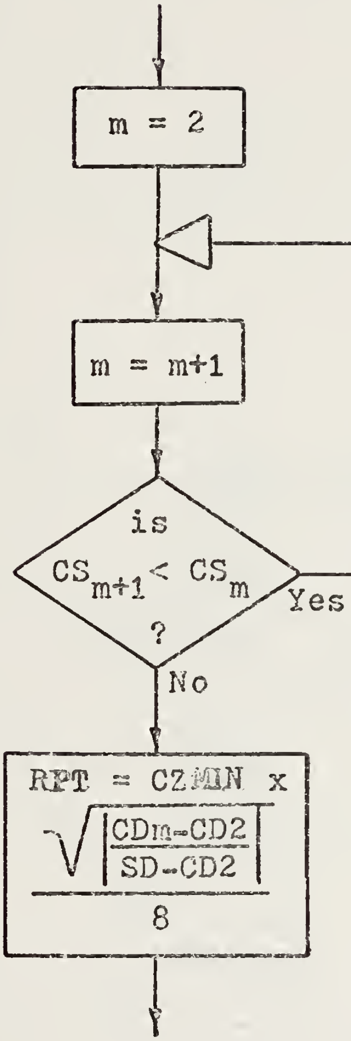
(17) Computation of RS, RT, SSL, DFL

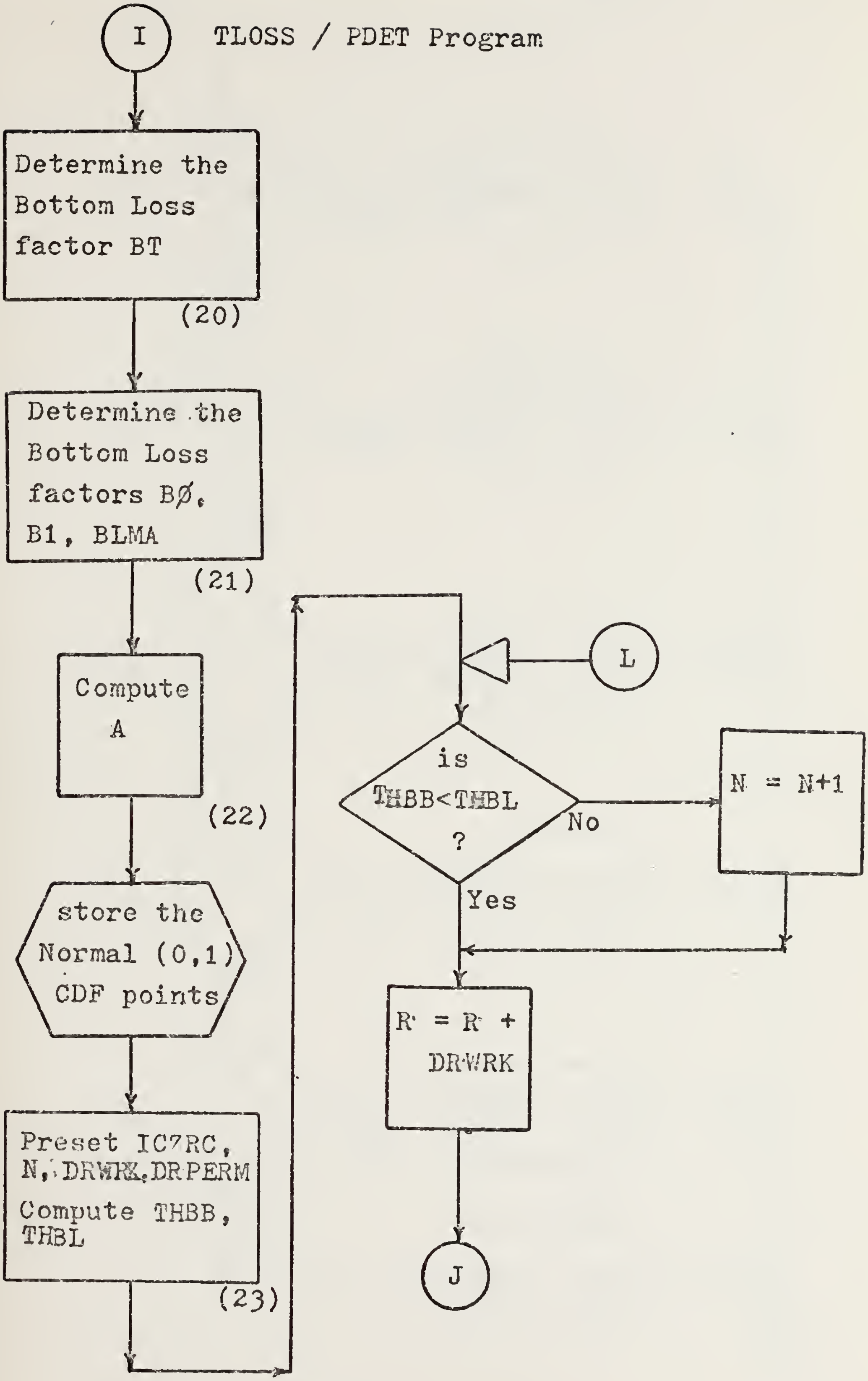

$RS = \arccos\left(\frac{CS(1)}{CS(2)}\right) \times (2CS(1) / 3) \times \left(\frac{(CD(2) - CD(1))}{(CS(2) - CS(1))}\right)$
$RS = \frac{CD(2)}{6 \arccos \frac{SV}{CS(2)}}$
$SSL = \frac{.8}{RS}\left(\frac{WH \times SF}{1000}\right)^{.71}$
$G = \left|\frac{CS(3)-CS(2)}{CD(3)-CD(2)}\right|$
$DFL = 744 \times \left(\frac{SF}{1000}\right)^{-5/3} \times G^{-1/3} \times CD(2)^{-3}$

(18) Computation of RL2

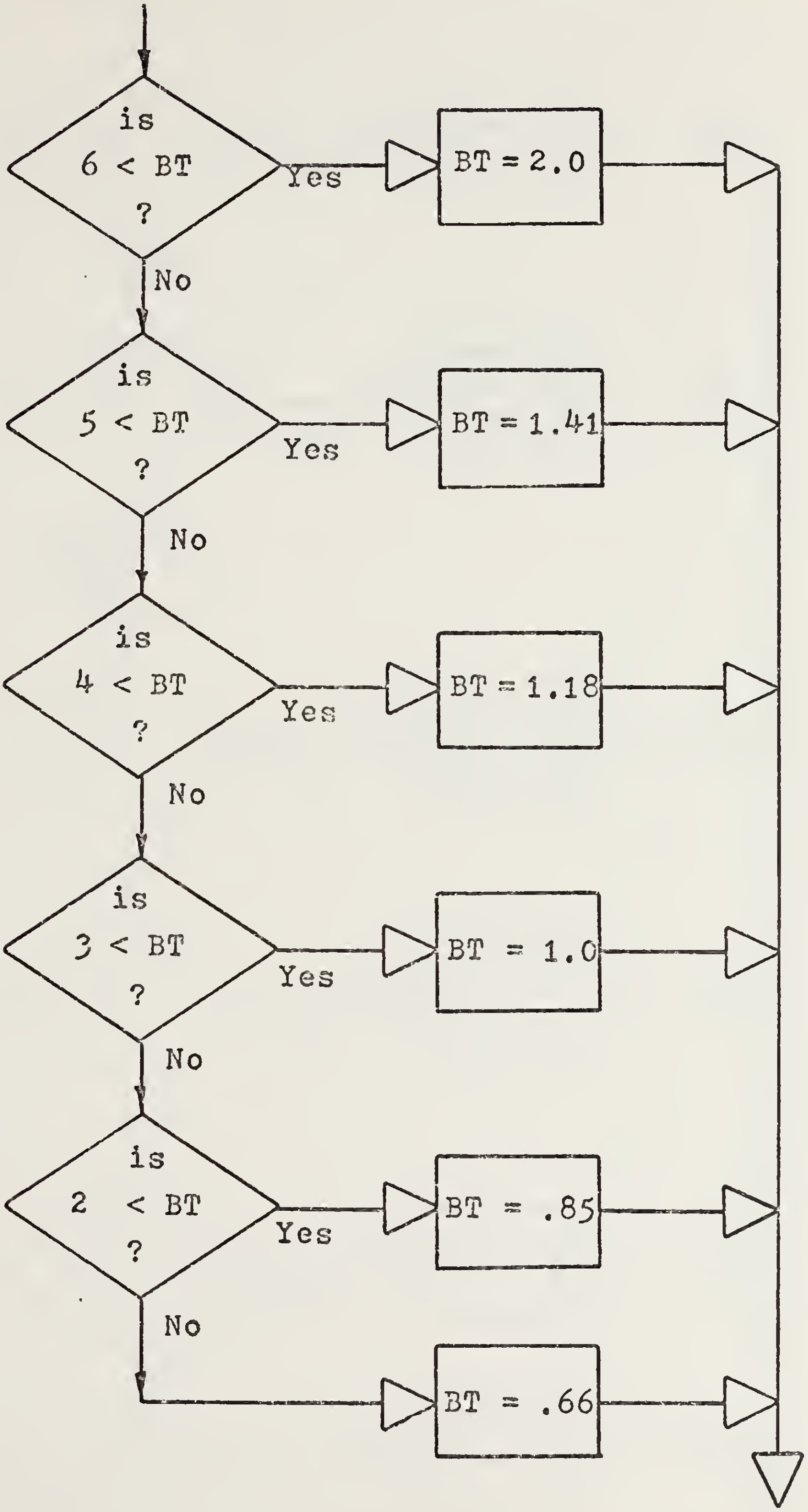


(19) Computation of RPT

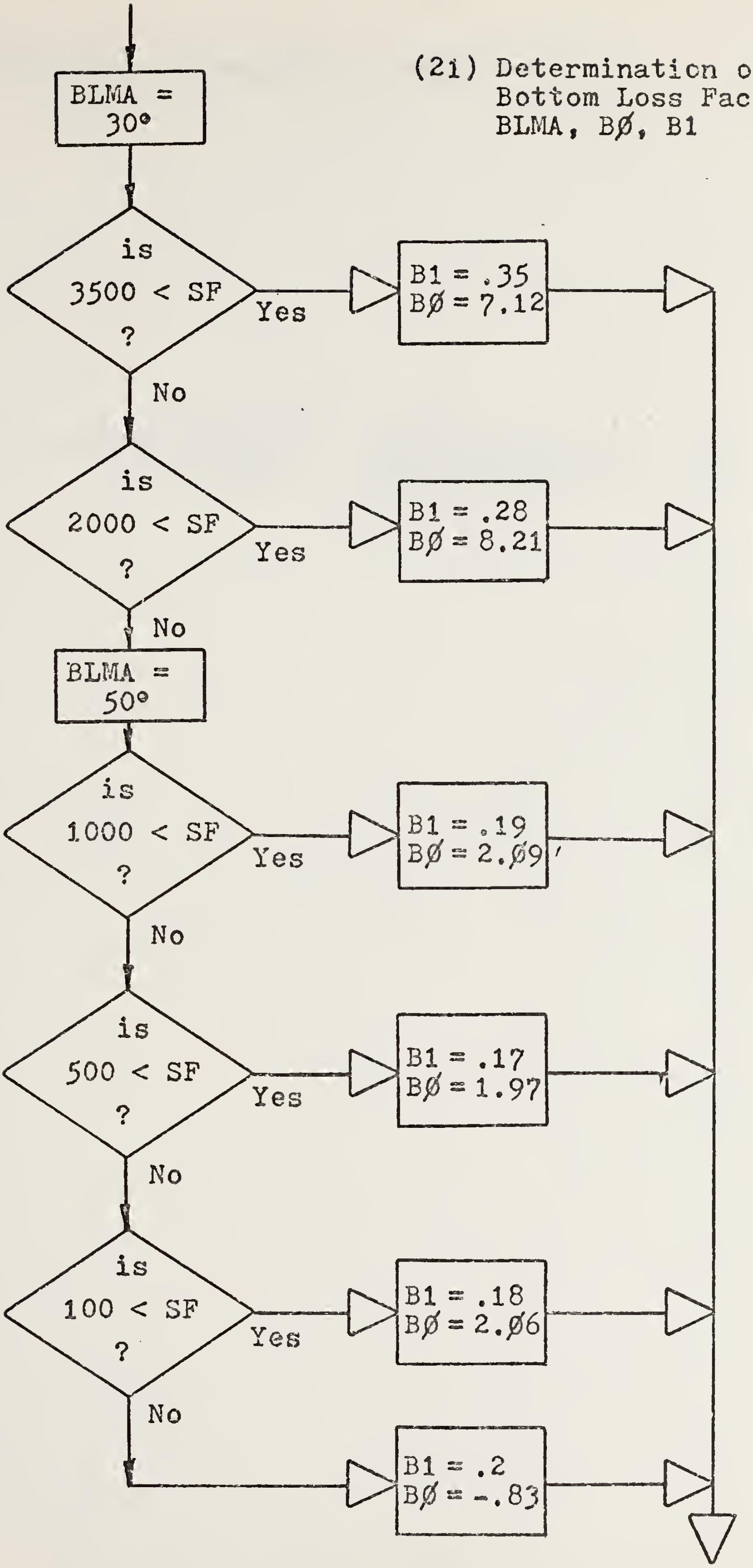

m = 2
m = m+1
is $CS_{m+1} < CS_m$?
Yes
No
RPT = CZMIN x $\frac{\sqrt{\left|\frac{CDm-CD2}{SD-CD2}\right|}}{8}$


I
TLOSS / PDET Program
Determine the Bottom Loss factor BT
(20)
Determine the Bottom Loss factors BØ, B1, BLMA
(21)
Compute A
(22)
store the Normal (0,1) CDF points
Preset IC7RC, N, DRWRK, DRPERM
Compute THBB, THBL
(23)
L
is THBB<THBL ?
No
N = N+1
Yes
R = R + DRWRK
J

(20) Bottom Loss Factor BT Determination



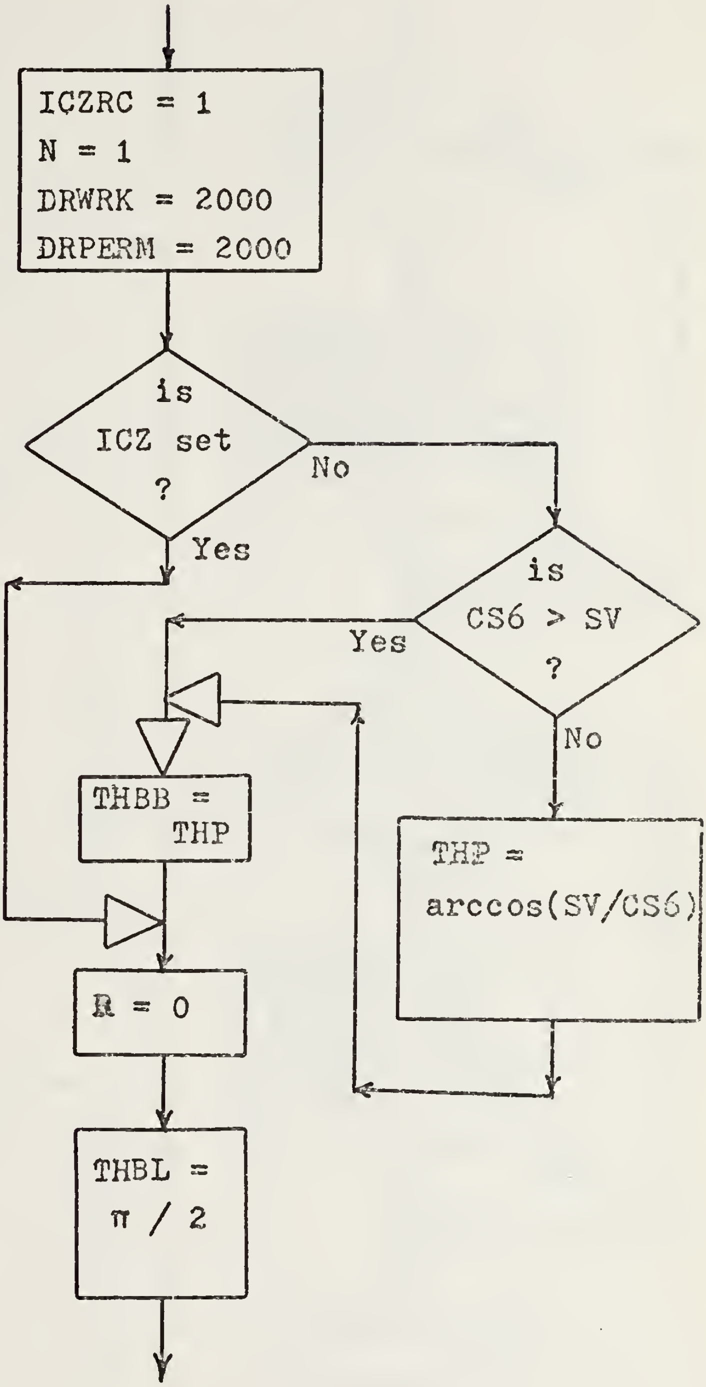
(2i) Determination of Bottom Loss Factors BLMA, B0, B1



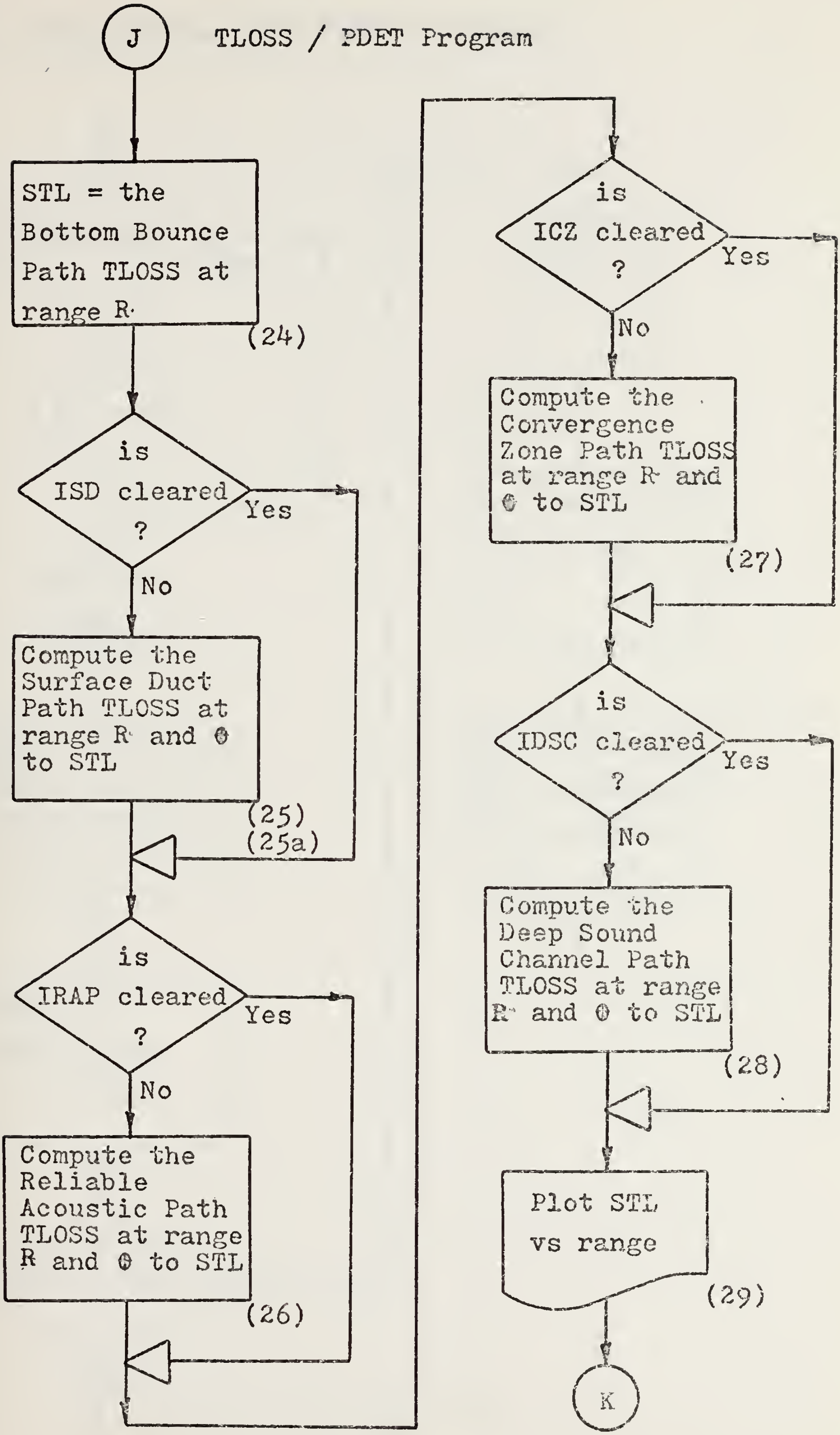
(22) Computation of Absorption Coefficient (A)

$$A = 1000\left(\frac{.1(SF/1000)^2}{1+(SF/1000)^2} + \frac{40(SF/1000)^2}{4100+(SF/1000)^2}\right) \quad \text{dB/yd}$$

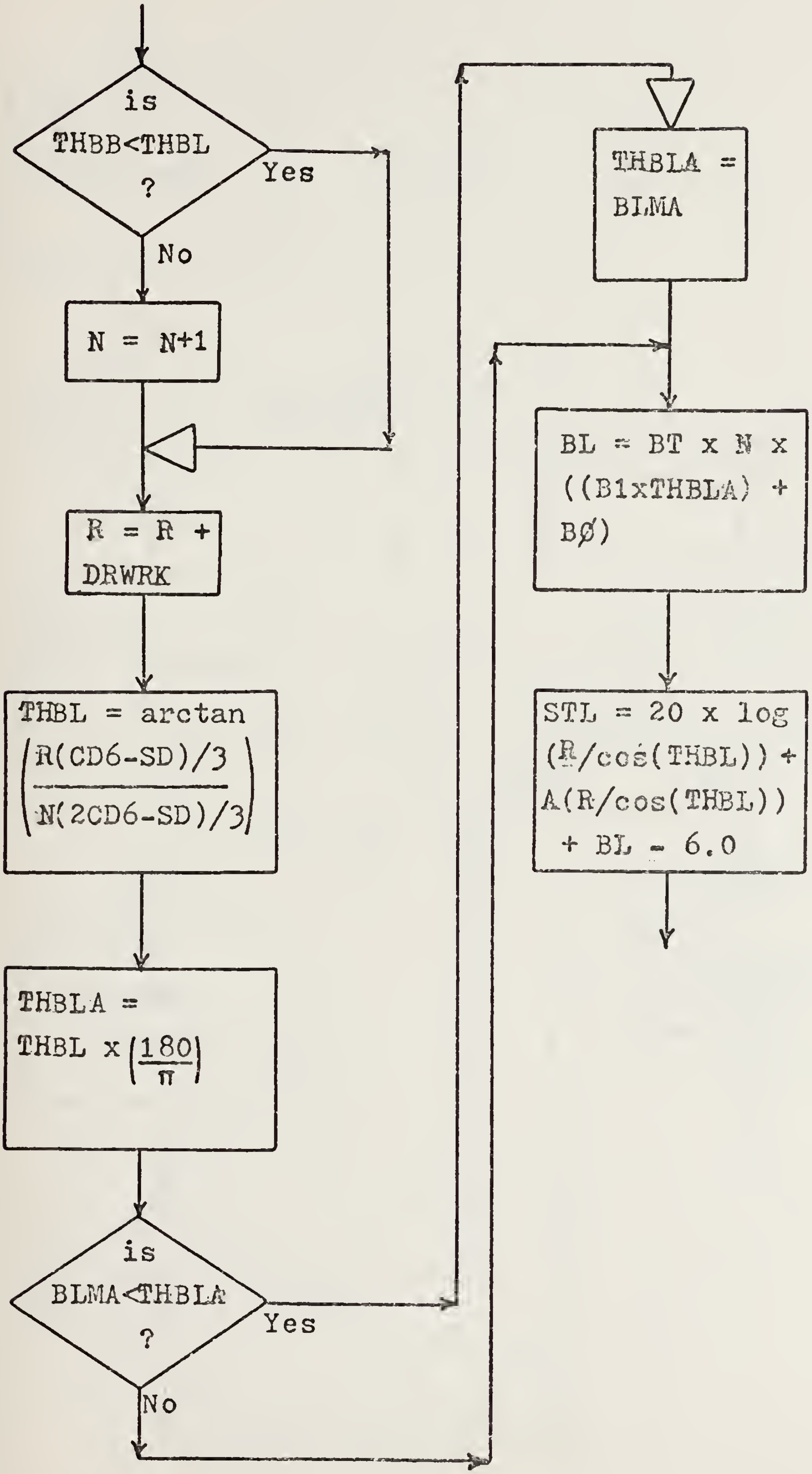
(23) Preset ICZRC, N, DRWRK, DRPERM
Compute THBB, THBL



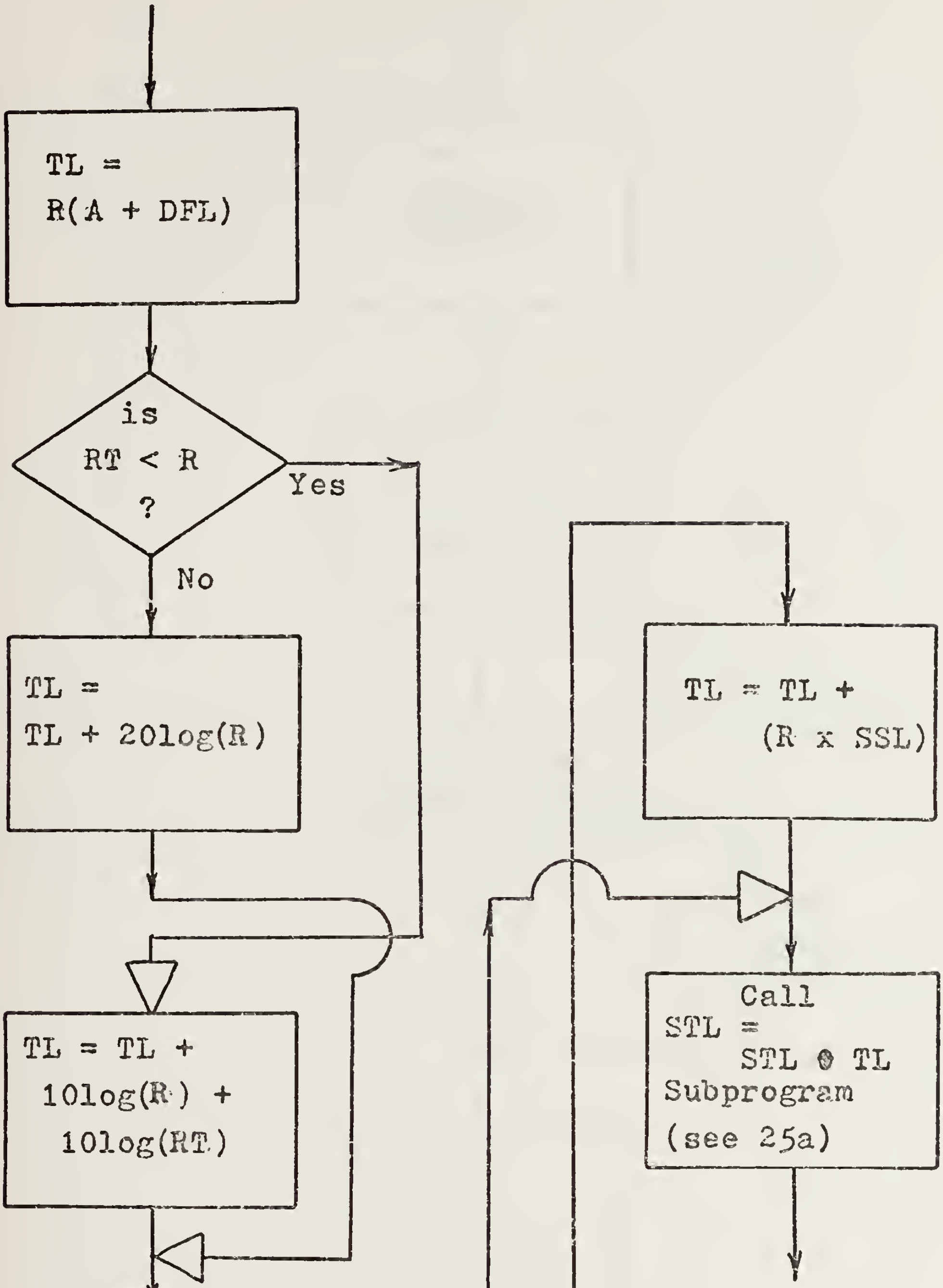
TLOSS / PDET Program


J
STL = the Bottom Bounce Path TLOSS at range R
(24)
is ISD cleared ?
Yes
No
Compute the Surface Duct Path TLOSS at range R and Θ to STL
(25)
(25a)
is IRAP cleared ?
Yes
No
Compute the Reliable Acoustic Path TLOSS at range R and Θ to STL
(26)
is ICZ cleared ?
Yes
No
Compute the Convergence Zone Path TLOSS at range R and Θ to STL
(27)
is IDSC cleared ?
Yes
No
Compute the Deep Sound Channel Path TLOSS at range R and Θ to STL
(28)
Plot STL vs range
(29)
K

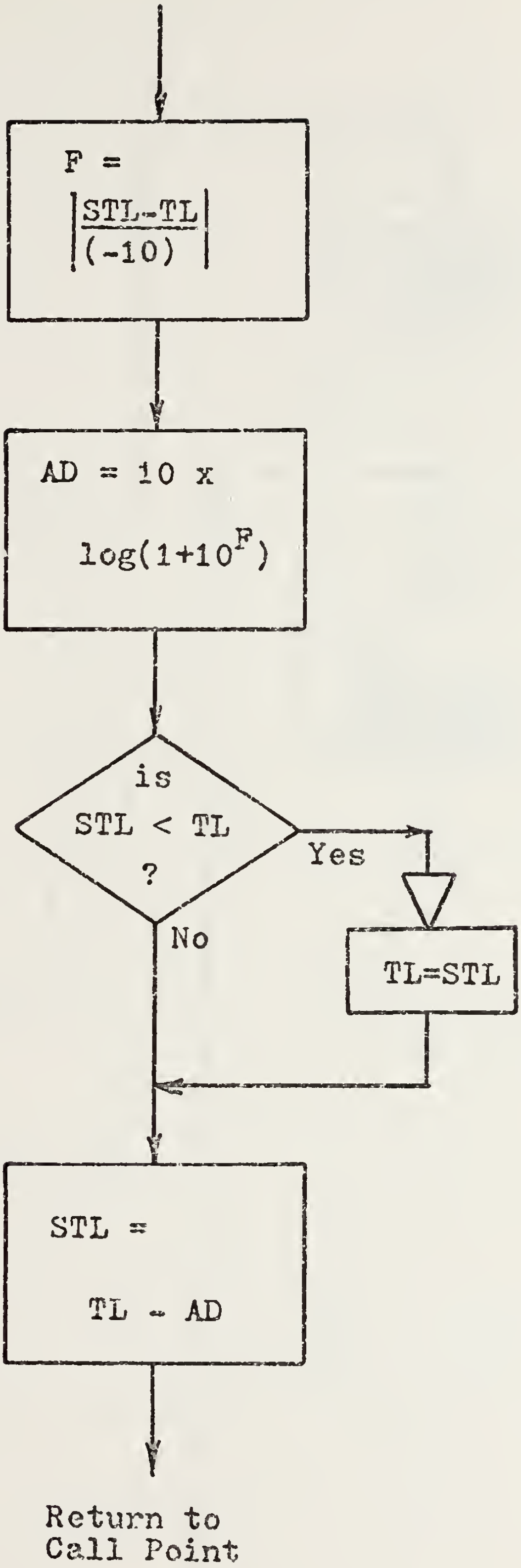
(24) Bottom Bounce Path TLOSS at Range R


is THBB<THBL ?
Yes
No
N = N+1
R = R + DRWRK
THBL = arctan (R(CD6-SD)/3 / N(2CD6-SD)/3)
THBLA = THBL x (180/π)
is BLMA<THBLA ?
Yes
No
THBLA = BLMA
BL = BT x N x ((B1xTHBLA) + B0)
STL = 20 x log (R/cos(THBL)) + A(R/cos(THBL)) + BL - 6.0

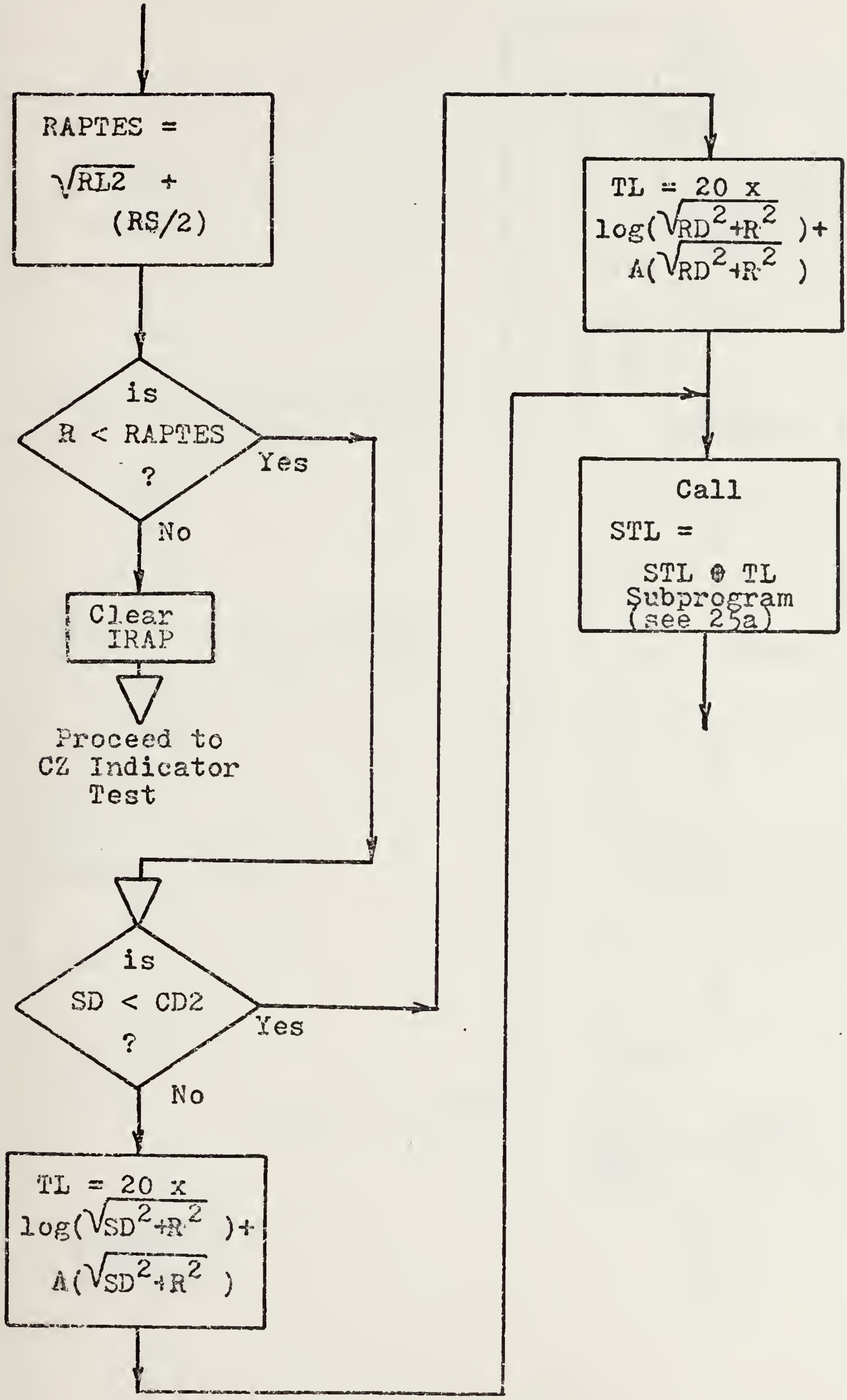
(25) Surface Duct Path TLOSS at Range R



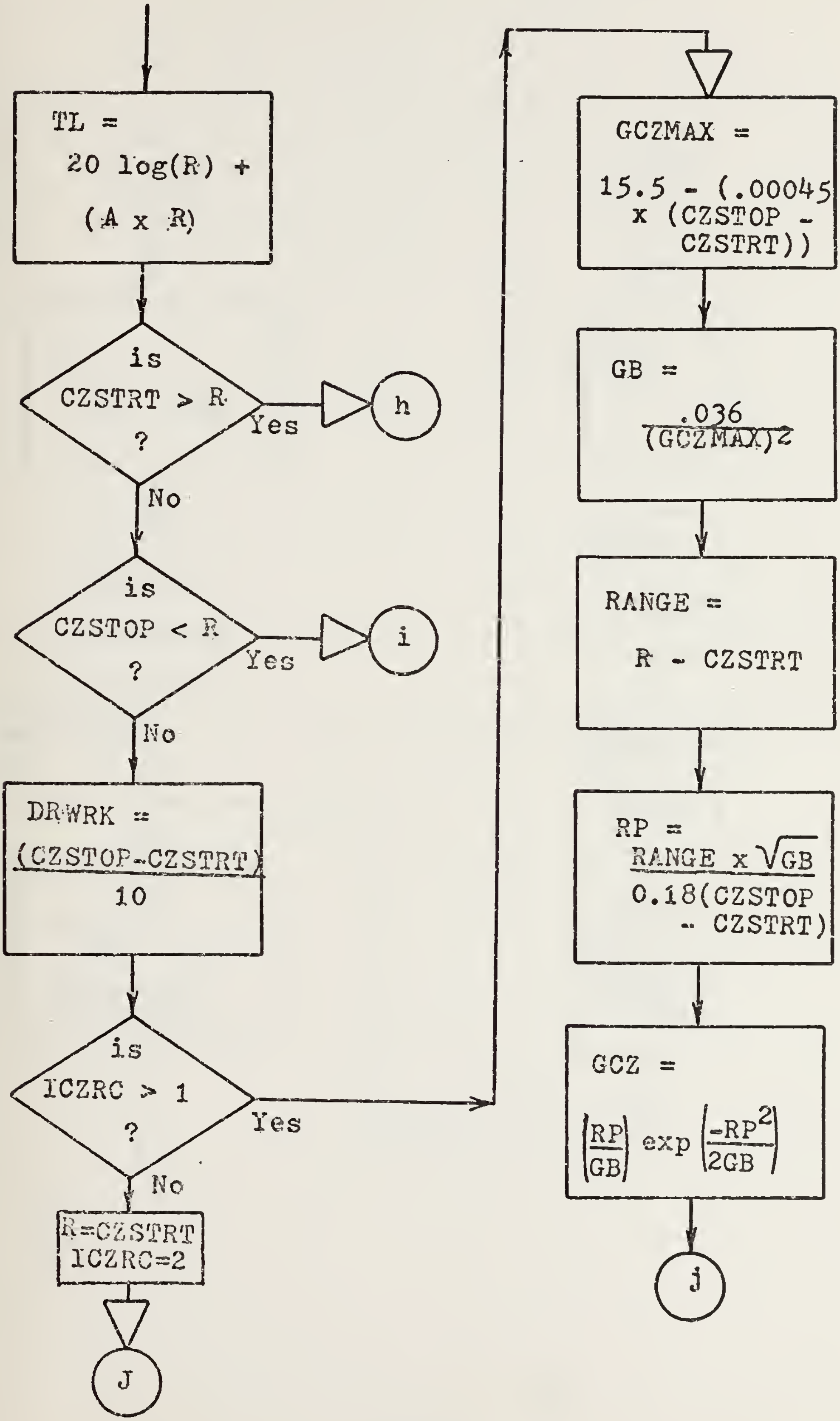
(25a) STL = STL $\ominus$ TL Subprogram


$F = \left|\frac{STL-TL}{(-10)}\right|$
$AD = 10 \times \log(1+10^F)$
is STL < TL ?
Yes
No
TL=STL
STL = TL - AD
Return to Call Point

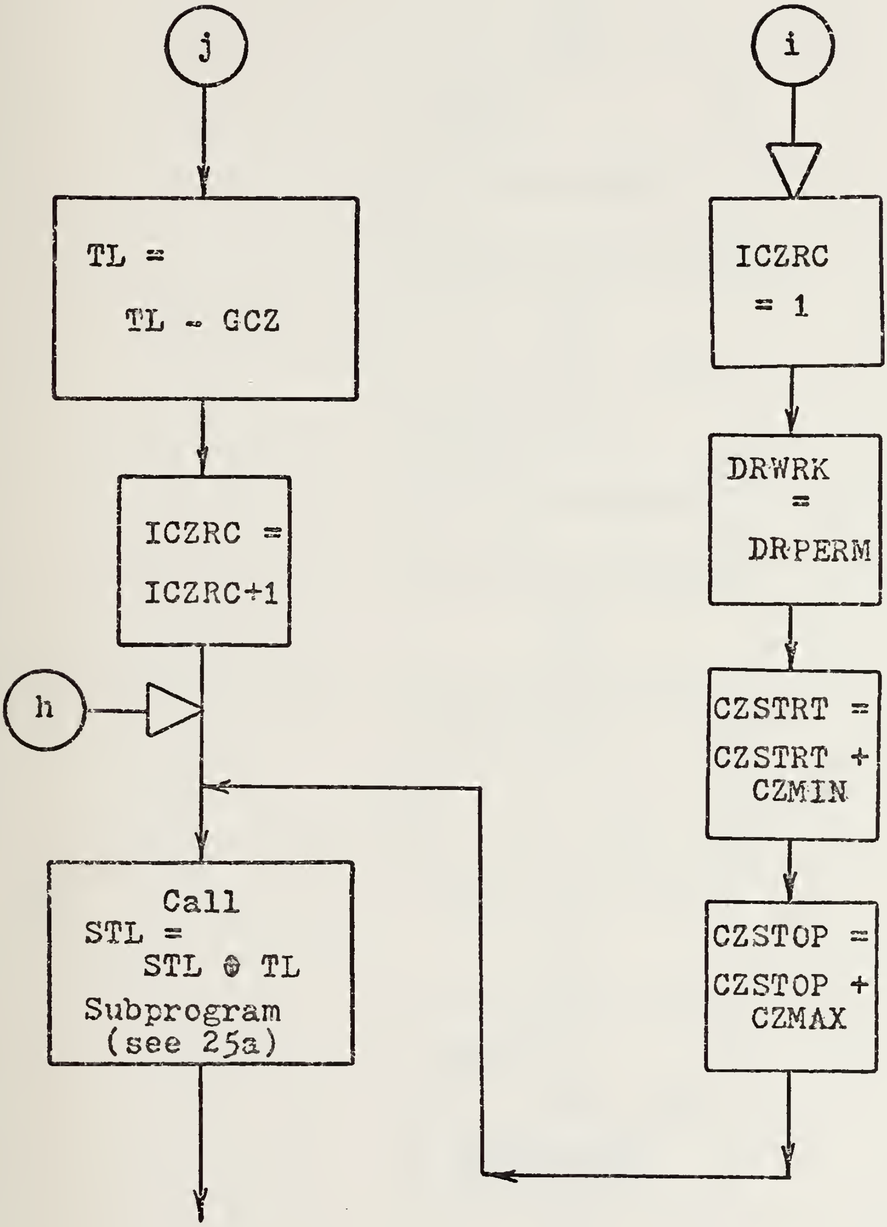
(26) Reliable Acoustic Path TLOSS at Range R


RAPTES = $\sqrt{RL2}$ + (RS/2)
is R < RAPTES ?
Yes
No
Clear IRAP
Proceed to CZ Indicator Test
is SD < CD2 ?
Yes
No
TL = 20 x log($\sqrt{SD^2+R^2}$)+ A($\sqrt{SD^2+R^2}$)
TL = 20 x log($\sqrt{RD^2+R^2}$)+ A($\sqrt{RD^2+R^2}$)
Call STL = STL ⊕ TL Subprogram (see 25a)

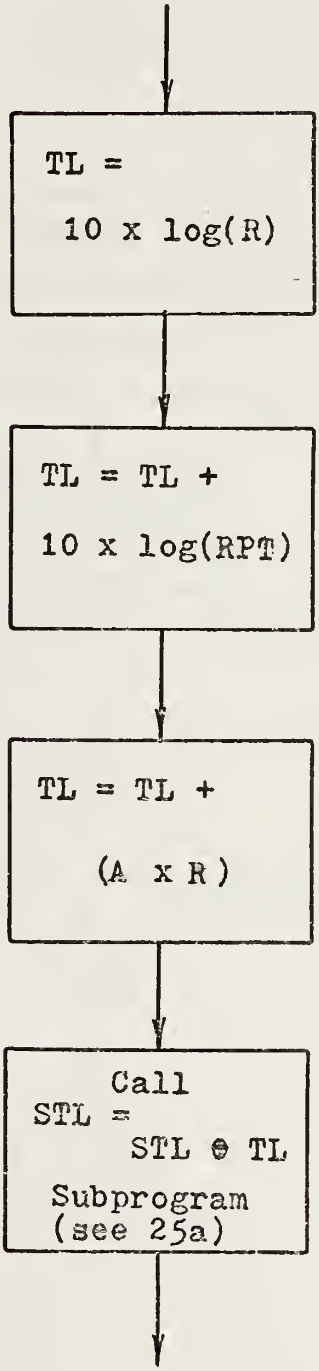
(27) Convergence Zone Path TLOSS at Range R



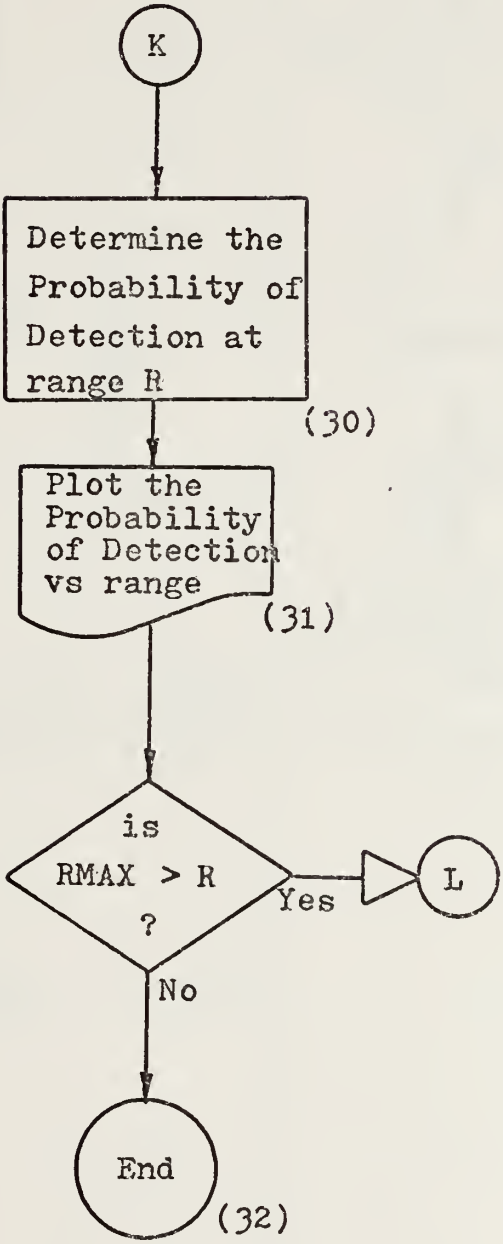
(27) Convergence Zone Path TLOSS at Range R



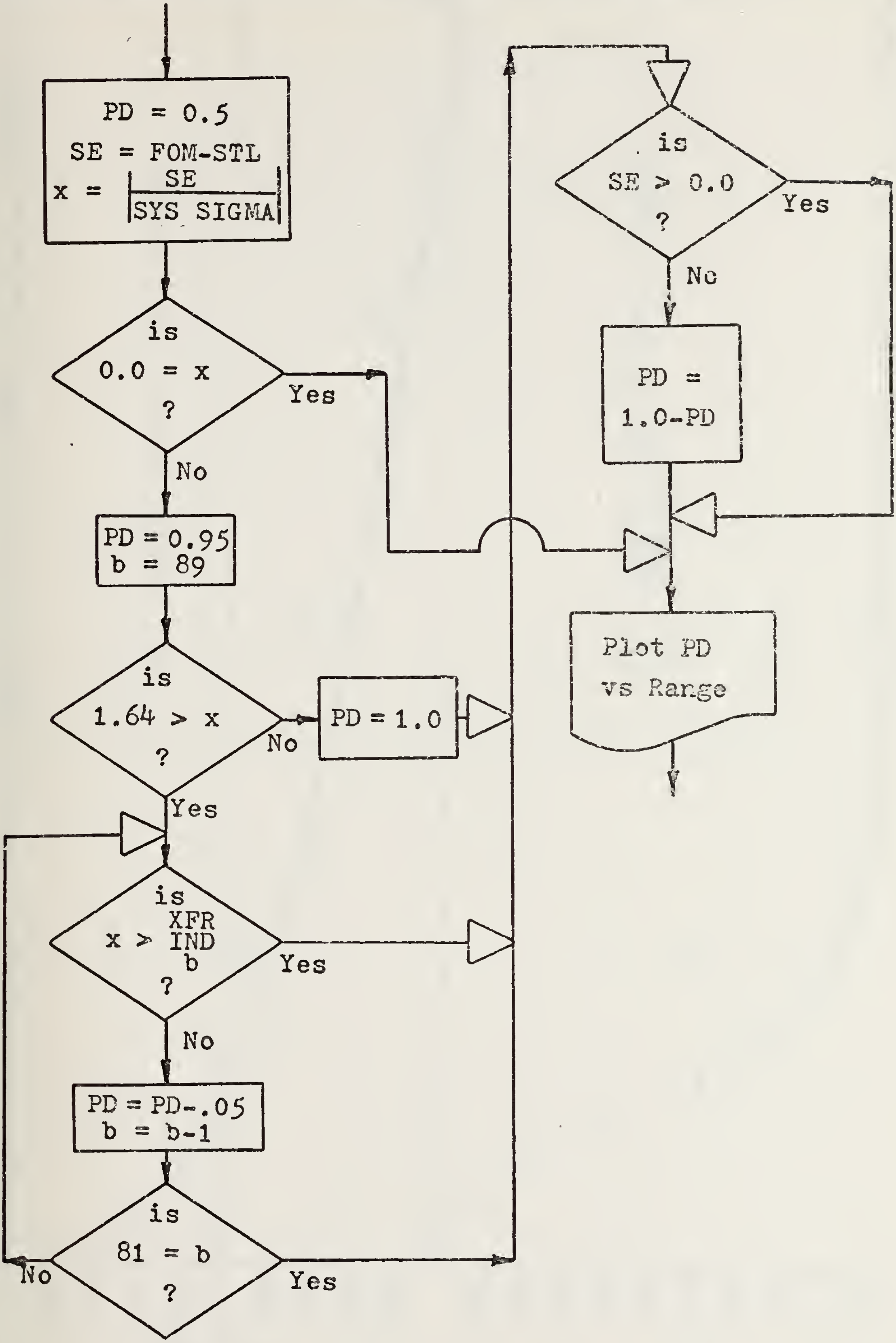
(28) Deep Sound Channel TLOSS at Range R

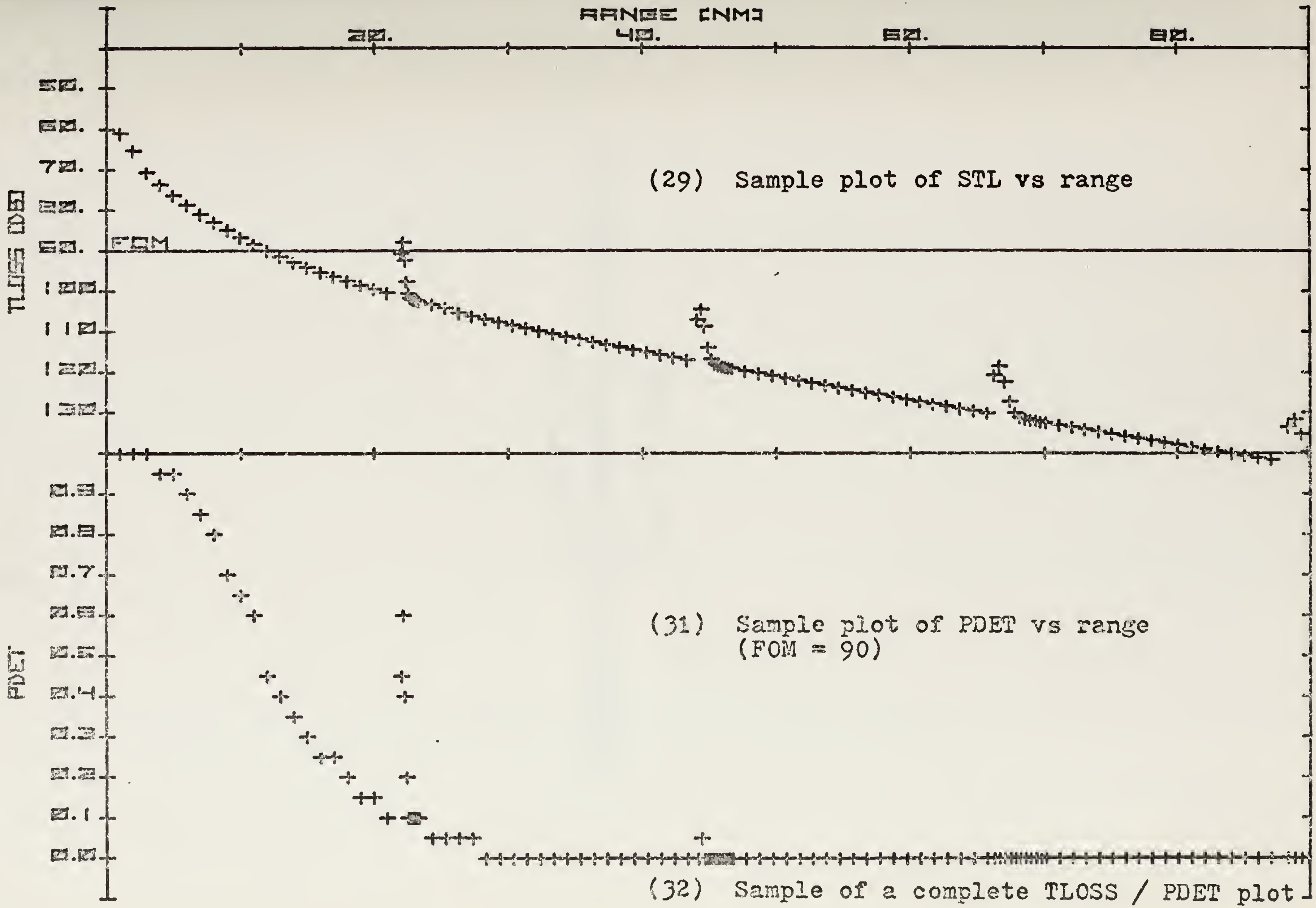


TLOSS / PDET Program


K
Determine the Probability of Detection at range R
(30)
Plot the Probability of Detection vs range
(31)
is RMAX > R ?
Yes
L
No
End
(32)

(30) Determination of Probability of Detection





(29) Sample plot of STL vs range

(31) Sample plot of PDET vs range
(FOM = 90)

(32) Sample of a complete TLOSS / PDET plot

PEAPS HP 9810A

Transmission Loss/Probability of Detection

Program Listing

```
0000--GTO---44
0001-- 6 ---06
0002-- 2 ---02
0003-- K ---55
0004-- 4 ---04
0005-- UP---27
0006-- 2 ---02
0007-- 0 ---00
0008-- X ---36
0009--S/R---77
0010-- K ---55
0011-- 4 ---04
0012-- UP---27
0013-- 1 ---01
0014-- 0 ---00
0015-- X ---36
0016--S/R---77
0017--XFR---67
0018-- 7 ---07
0019-- 4 ---04
0020-- UP---27
0021--XFR---67
0022-- 7 ---07
0023-- 5 ---05
0024-- - ---34
0025-- G ---15
0026-- DN---25
0027--CHS---32
0028-- UP---27
0029-- 1 ---01
0030-- 0 ---00
0031--DIV---35
0032-- H ---74
0033-- UP---27
0034-- 1 ---01
0035-- + ---33
0036-- DN---25
0037-- K ---55
0038-- 4 ---04
0039-- UP---27
0040-- 1 ---01
0041-- 0 ---00
0042-- X ---36
0043--XFR---67
0044-- 7 ---07
0045-- 5 ---05
0046-- UP---27
0047--XFR---67
0048-- 7 ---07
0049-- 4 ---04
0050--X<Y---52
0051--CNT---47
0052--KEY---30
0053--CNT---47
0054--CNT---47
0055-- DN---25
0056--KEY---30
0057-- - ---34
0058--YTO---40
0059-- 7 ---07
0060-- 4 ---04
0061--S/R---77
0062-- 1 ---01
0063-- 8 ---10
0064-- 0 ---00
0065-- UP---27
0066-- π ---56
0067--DIV---35
0068--YTO---40
0069-- 7 ---07
0070-- 9 ---11
0071--FMT---42
0072-- 1 ---01
0073-- 8 ---10
0074-- 2 ---02
0075--FMT---42
0076--FMT---42
0077--CLR---20
0078-- F ---16
0079-- a ---13
0080-- E ---60
0081-- b ---14
0082--FMT---42
0083--STP---41
0084--XTO---23
0085-- 6 ---06
0086--PNT---45
0087--FMT---42
0088--FMT---42
0089-- F ---16
0090-- O ---71
0091-- M ---70
0092--FMT---42
0093--STP---41
0094--XTO---23
0095-- 6 ---06
0096-- 1 ---01
0097--PNT---45
0098--FMT---42
0099--FMT---42
0100--YTO---40
0101-- I ---65
0102-- G ---15
0103-- M ---70
0104-- A ---62
0105--FMT---42
0106--STP---41
0107--XTO---23
0108-- 6 ---06
0109-- 2 ---02
0110--PNT---45
0111--FMT---42
0112--FMT---42
0113--IND---31
0114-- A ---62
0115--INT---64
0116-- E ---60
0117--CNT---47
0118-- H ---74
0119--XTO---23
0120--FMT---42
0121--STP---41
0122--XTO---23
0123-- 6 ---06
0124-- 0 ---00
0125--PNT---45
0126--FMT---42
0127--FMT---42
0128-- a ---13
0129-- C ---61
0130--INT---64
0131-- a ---13
0132--CNT---47
0133-- D ---63
0134-- E ---60
0135-- π ---56
0136--XTO---23
0137-- H ---74
0138--FMT---42
0139--STP---41
0140--PNT---45
0141--XTO---23
0142-- 6 ---06
0143-- 4 ---04
0144--FMT---42
0145--FMT---42
0146-- B ---66
0147-- O ---71
0148--XTO---23
0149--CNT---47
0150--XTO---23
0151--XFR---67
0152-- π ---56
0153-- E ---60
0154--FMT---42
0155--STP---41
0156--XTO---23
0157-- 6 ---06
0158-- 5 ---05
0159--PNT---45
0160--FMT---42
0161-- 1 ---01
```

```
0162-- 8 ---10
0163-- 0 ---00
0164-- . ---21
0165-- 1 ---01
0166--FMT---42
0167-- 1 ---01
0168-- 1 ---01
0169--XFR---67
0170-- 6 ---06
0171-- 1 ---01
0172--XTO---23
0173-- a ---13
0174-- UP---27
0175-- 8 ---10
0176-- 0 ---00
0177--X>Y---53
0178--XTO---23
0179-- a ---13
0180--CNT---47
0181--CNT---47
0182-- 1 ---01
0183-- 0 ---00
0184-- 0 ---00
0185--X<Y---52
0186--XTO---23
0187-- a ---13
0188--CNT---47
0189--CNT---47
0190-- a ---13
0191-- UP---27
0192-- 1 ---01
0193-- 5 ---05
0194-- + ---33
0195-- 2 ---02
0196-- 0 ---00
0197--DIV---35
0198-- 1 ---01
0199-- 0 ---00
0200-- H ---74
0201--XTO---23
0202-- 1 ---01
0203--XTO---23
0204-- a ---13
0205-- UP---27
0206-- 2 ---02
0207--EEX---26
0208-- 4 ---04
0209--DIV---35
0210-- DN---25
0211--INT---64
0212-- UP---27
0213-- 1 ---01
0214-- + ---33
0215-- 2 ---02
```

```
0216--EEX---26
0217-- 4 ---04
0218-- X ---36
0219--YTO---40
0220-- 6 ---06
0221-- 3 ---03
0222-- . ---21
0223-- 1 ---01
0224--XFR---67
0225-- X ---36
0226-- a ---13
0227--CHS---32
0228--XTO---23
0229-- 2 ---02
0230--FMT---42
0231-- 1 ---01
0232-- 2 ---02
0233--CHS---32
0234-- 3 ---03
0235-- 0 ---00
0236-- UP---27
0237--CHS---32
0238-- 2 ---02
0239-- 5 ---05
0240-- 0 ---00
0241--FMT---42
0242-- 1 ---01
0243-- 3 ---03
0244--CHS---32
0245-- 4 ---04
0246-- 0 ---00
0247-- UP---27
0248-- 0 ---00
0249--FMT---42
0250-- 1 ---01
0251-- UP---27
0252-- 2 ---02
0253--EEX---26
0254-- 4 ---04
0255--FMT---42
0256-- 1 ---01
0257-- 5 ---05
0258-- 1 ---01
0259-- 0 ---00
0260--FMT---42
0261-- 1 ---01
0262-- 6 ---06
0263--CHS---32
0264-- 1 ---01
0265-- 4 ---04
0266-- 0 ---00
0267-- UP---27
0268-- 0 ---00
0269--FMT---42
```

```
0270-- 1 ---01
0271-- UP---27
0272-- 2 ---02
0273--EEX---26
0274-- 4 ---04
0275--FMT---42
0276-- 1 ---01
0277-- 5 ---05
0278--CHS---32
0279-- 4 ---04
0280-- 0 ---00
0281-- UP---27
0282--XFR---67
0283-- 6 ---06
0284-- 3 ---03
0285--FMT---42
0286-- 1 ---01
0287-- UP---27
0288-- 1 ---01
0289-- 0 ---00
0290--FMT---42
0291-- 1 ---01
0292-- 6 ---06
0293--CHS---32
0294-- 3 ---03
0295-- 3 ---03
0296-- UP---27
0297-- . ---21
0298-- 4 ---04
0299--XFR---67
0300-- X ---36
0301-- a ---13
0302--FMT---42
0303-- 1 ---01
0304-- UP---27
0305--FMT---42
0306-- 1 ---01
0307--FMT---42
0308-- a ---13
0309-- A ---62
0310-- N ---73
0311-- G ---15
0312-- E ---60
0313--CNT---47
0314--X<Y---52
0315-- N ---73
0316-- M ---70
0317--PSE---57
0318--FMT---42
0319-- 2 ---02
0320-- 0 ---00
0321--XTO---23
0322-- 0 ---00
0323--XTO---23
```

```
0324-- a ---13
0325-- 4 ---04
0326--EEX---26
0327-- 4 ---04
0328--XTO---23
0329-- 9 ---11
0330-- 9 ---11
0331-- UP---27
0332-- . ---21
0333-- 0 ---00
0334-- 2 ---02
0335--XFR---67
0336-- X ---36
0337-- 1 ---01
0338-- - ---34
0339--YTO---40
0340-- b ---14
0341--XFR---67
0342-- 1 ---01
0343-- UP---27
0344--EEX---26
0345-- 4 ---04
0346-- - ---34
0347--YTO---40
0348-- 3 ---03
0349--CHS---32
0350-- 3 ---03
0351-- 8 ---10
0352-- UP---27
0353-- b ---14
0354--FMT---42
0355-- 1 ---01
0356-- UP---27
0357-- a ---13
0358--FMT---42
0359-- 1 ---01
0360--PNT---45
0361--XFR---67
0362-- 9 ---11
0363-- 9 ---11
0364--XTO---23
0365-- + ---33
0366-- b ---14
0367--XFR---67
0368-- 0 ---00
0369--XTO---23
0370-- + ---33
0371-- a ---13
0372--XFR---67
0373-- 6 ---06
0374-- 3 ---03
0375-- UP---27
0376-- b ---14
0377--X<Y---52
0378-- 0 ---00
0379-- 3 ---03
0380-- 4 ---04
0381-- 9 ---11
0382--CHS---32
0383-- 5 ---05
0384-- 0 ---00
0385--XTO---23
0386-- a ---13
0387--XFR---67
0388-- 2 ---02
0389-- UP---27
0390-- . ---21
0391-- 5 ---05
0392-- 5 ---05
0393-- X ---36
0394--YTO---40
0395-- b ---14
0396-- a ---13
0397-- UP---27
0398-- b ---14
0399--FMT---42
0400-- 1 ---01
0401-- UP---27
0402-- a ---13
0403--CHS---32
0404--FMT---42
0405-- 1 ---01
0406--PNT---45
0407-- 1 ---01
0408-- 0 ---00
0409--XTO---23
0410-- - ---34
0411-- a ---13
0412-- a ---13
0413-- UP---27
0414--CHS---32
0415-- 1 ---01
0416-- 4 ---04
0417-- 0 ---00
0418--X<Y---52
0419-- 0 ---00
0420-- 3 ---03
0421-- 9 ---11
0422-- 8 ---10
0423--CHS---32
0424-- 1 ---01
0425-- 5 ---05
0426-- 0 ---00
0427--XTO---23
0428-- b ---14
0429-- . ---21
0430-- 9 ---11
0431--XTO---23
0432-- a ---13
0433-- . ---21
0434-- 4 ---04
0435-- 5 ---05
0436--XFR---67
0437-- X ---36
0438-- 2 ---02
0439--XTO---23
0440-- 0 ---00
0441--FMT---42
0442-- 1 ---01
0443-- 8 ---10
0444-- 1 ---01
0445-- b ---14
0446-- UP---27
0447--XFR---67
0448-- 0 ---00
0449--FMT---42
0450-- 1 ---01
0451-- UP---27
0452-- a ---13
0453--FMT---42
0454-- 1 ---01
0455--PNT---45
0456-- . ---21
0457-- 1 ---01
0458--XTO---23
0459-- - ---34
0460-- a ---13
0461-- 1 ---01
0462-- 0 ---00
0463--XTO---23
0464-- - ---34
0465-- b ---14
0466-- b ---14
0467-- UP---27
0468--CHS---32
0469-- 2 ---02
0470-- 5 ---05
0471-- 0 ---00
0472--X<Y---52
0473-- 0 ---00
0474-- 4 ---04
0475-- 4 ---04
0476-- 7 ---07
0477--XFR---67
0478-- 6 ---06
0479-- 1 ---01
0480-- UP---27
0481-- 2 ---02
0482-- 3 ---03
0483-- 3 ---03
0484--X<Y---52
0485-- 0 ---00
```

```
0486-- 5 ---05
0487-- 2 ---02
0488-- 4 ---04
0489--XFR---67
0490-- 6 ---06
0491-- 1 ---01
0492--CHS---32
0493-- UP---27
0494--YTO---40
0495-- a ---13
0496-- 0 ---00
0497--FMT---42
0498-- 1 ---01
0499-- UP---27
0500-- a ---13
0501-- UP---27
0502--XFR---67
0503-- 6 ---06
0504-- 3 ---03
0505--FMT---42
0506-- 1 ---01
0507-- DN---25
0508-- a ---13
0509-- UP---27
0510-- 1 ---01
0511-- + ---33
0512--EEX---26
0513-- 3 ---03
0514--FMT---42
0515-- 1 ---01
0516-- UP---27
0517--FMT---42
0518-- 1 ---01
0519--FMT---42
0520-- F ---16
0521-- O ---71
0522-- M ---70
0523--FMT---42
0524--FMT---42
0525-- 1 ---01
0526-- 9 ---11
0527--CHS---32
0528-- 1 ---01
0529-- 0 ---00
0530-- 5 ---05
0531-- UP---27
0532--XFR---67
0533-- 2 ---02
0534-- UP---27
0535-- . ---21
0536-- 3 ---03
0537--XFR---67
0538-- X ---36
0539-- 2 ---02
0540-- - ---34
0541-- DN---25
0542--XTO---23
0543-- 3 ---03
0544--FMT---42
0545-- 1 ---01
0546-- UP---27
0547--FMT---42
0548-- 1 ---01
0549--FMT---42
0550--XTO---23
0551-- L ---72
0552-- O ---71
0553--YTO---40
0554--YTO---40
0555--CNT---47
0556--X<Y---52
0557-- D ---63
0558-- B ---66
0559--PSE---57
0560--FMT---42
0561--CHS---32
0562-- 2 ---02
0563-- 0 ---00
0564-- 0 ---00
0565-- UP---27
0566--XFR---67
0567-- 3 ---03
0568--FMT---42
0569-- 1 ---01
0570-- UP---27
0571--FMT---42
0572-- 1 ---01
0573--FMT---42
0574-- π ---56
0575-- D ---63
0576-- E ---60
0577--XTO---23
0578--FMT---42
0579--FMT---42
0580-- 1 ---01
0581-- 9 ---11
0582--XFR---67
0583-- 1 ---01
0584-- 7 ---07
0585-- UP---27
0586--XFR---67
0587-- 1 ---01
0588-- 8 ---10
0589--X<Y---52
0590-- 0 ---00
0591-- 8 ---10
0592-- 2 ---02
0593-- 6 ---06
0594--XFR---67
0595-- 1 ---01
0596-- 2 ---02
0597-- UP---27
0598--XFR---67
0599-- 4 ---04
0600--X>Y---53
0601-- 0 ---00
0602-- 7 ---07
0603-- 7 ---07
0604-- 0 ---00
0605--XFR---67
0606-- 6 ---06
0607-- 4 ---04
0608--X>Y---53
0609-- 0 ---00
0610-- 7 ---07
0611-- 2 ---02
0612-- 6 ---06
0613-- 1 ---01
0614--XTO---23
0615-- 2 ---02
0616-- 3 ---03
0617--XFR---67
0618-- 5 ---05
0619--XFR---67
0620--DIV---35
0621-- 1 ---01
0622-- 8 ---10
0623-- L ---72
0624-- N ---73
0625--1/X---17
0626--XFR---67
0627-- X ---36
0628-- 1 ---01
0629-- 2 ---02
0630-- UP---27
0631-- 6 ---06
0632--DIV---35
0633--YTO---40
0634-- 7 ---07
0635-- 0 ---00
0636--XFR---67
0637-- 1 ---01
0638-- 7 ---07
0639-- UP---27
0640-- UP---27
0641--XFR---67
0642-- 1 ---01
0643-- 8 ---10
0644--DIV---35
0645--RUP---22
0646-- - ---34
0647--XFR---67
```

```
0648-- 1 ---01
0649-- 2 ---02
0650--XFR---67
0651-- - ---34
0652-- 1 ---01
0653-- 1 ---01
0654--DIV---35
0655--XFR---67
0656-- 1 ---01
0657-- 7 ---07
0658--XEY---30
0659--DIV---35
0660-- 2 ---02
0661-- X ---36
0662-- 3 ---03
0663--DIV---35
0664-- DN---25
0665--XEY---30
0666-- L ---72
0667-- H ---73
0668-- X ---36
0669--YTO---40
0670-- 6 ---06
0671-- 9 ---11
0672-- . ---21
0673-- 8 ---10
0674--XEY---30
0675--DIV---35
0676-- . ---21
0677-- 7 ---07
0678-- 1 ---01
0679-- UP---27
0680--EEX---26
0681-- 3 ---03
0682--1/X---17
0683--XFR---67
0684-- X ---36
0685-- 6 ---06
0686--XFR---67
0687-- X ---36
0688-- 6 ---06
0689-- 0 ---00
0690-- H ---74
0691--RUP---22
0692-- X ---36
0693--YTO---40
0694-- 7 ---07
0695-- 1 ---01
0696--CLX---37
0697-- 5 ---05
0698-- UP---27
0699-- 3 ---03
0700--DIV---35
0701--EEX---26
```

```
0702-- 3 ---03
0703--1/X---17
0704--XFR---67
0705-- X ---36
0706-- 6 ---06
0707-- H ---74
0708--1/X---17
0709-- UP---27
0710--XFR---67
0711-- 1 ---01
0712-- 9 ---11
0713--XFR---67
0714-- - ---34
0715-- 1 ---01
0716-- 8 ---10
0717-- UP---27
0718--XFR---67
0719-- 1 ---01
0720-- 3 ---03
0721--XFR---67
0722-- - ---34
0723-- 1 ---01
0724-- 2 ---02
0725--DIV---35
0726-- G ---15
0727-- 3 ---03
0728--1/X---17
0729--XEY---30
0730-- H ---74
0731--1/X---17
0732--XEY---30
0733-- DN---25
0734-- X ---36
0735-- 3 ---03
0736-- UP---27
0737--XFR---67
0738-- 1 ---01
0739-- 2 ---02
0740-- H ---74
0741--1/X---17
0742--XEY---30
0743-- DN---25
0744-- X ---36
0745-- 7 ---07
0746-- 4 ---04
0747-- 4 ---04
0748-- X ---36
0749--YTO---40
0750-- 7 ---07
0751-- 2 ---02
0752--XFR---67
0753-- 5 ---05
0754-- 8 ---10
0755-- UP---27
```

```
0756-- 1 ---01
0757--X=Y---50
0758--CLX---37
0759--XTO---23
0760-- 7 ---07
0761-- 2 ---02
0762--CLX---37
0763--XTO---23
0764-- 2 ---02
0765-- 7 ---07
0766--GTO---44
0767-- 8 ---10
0768-- 3 ---03
0769-- 4 ---04
0770--XFR---67
0771-- 6 ---06
0772-- 4 ---04
0773--X>Y---53
0774-- 0 ---00
0775-- 8 ---10
0776-- 2 ---02
0777-- 2 ---02
0778-- 1 ---01
0779--XTO---23
0780-- 2 ---02
0781-- 7 ---07
0782--XFR---67
0783-- 1 ---01
0784-- 3 ---03
0785--XFR---67
0786-- - ---34
0787-- 1 ---01
0788-- 2 ---02
0789-- UP---27
0790--XFR---67
0791-- 1 ---01
0792-- 8 ---10
0793-- X ---36
0794--XFR---67
0795-- - ---34
0796-- 1 ---01
0797-- 9 ---11
0798--DIV---35
0799--XFR---67
0800-- 1 ---01
0801-- 2 ---02
0802-- UP---27
0803--XFR---67
0804-- 4 ---04
0805--X<Y---52
0806--XFR---67
0807-- 6 ---06
0808-- 4 ---04
0809--CNT---47
```

```
0810--XEY---30
0811-- - ---34
0812-- DN---25
0813-- X ---36
0814-- 4 ---04
0815-- . ---21
0816-- 5 ---05
0817--CNT---47
0818--DIV---35
0819--YTO---40
0820-- 9 ---11
0821-- 5 ---05
0822--GTO---44
0823-- 8 ---10
0824-- 3 ---03
0825-- 0 ---00
0826--CLX---37
0827--XTO---23
0828-- 2 ---02
0829-- 7 ---07
0830--CLX---37
0831--XTO---23
0832-- 2 ---02
0833-- 3 ---03
0834--XFR---67
0835-- 2 ---02
0836-- 6 ---06
0837-- UP---27
0838-- 1 ---01
0839--X=Y---50
0840-- 0 ---00
0841-- 8 ---10
0842-- 4 ---04
0843-- 8 ---10
0844--GTO---44
0845-- 8 ---10
0846-- 8 ---10
0847-- 1 ---01
0848--XFR---67
0849-- 8 ---10
0850--XTO---23
0851-- 9 ---11
0852-- 3 ---03
0853--XFR---67
0854-- 9 ---11
0855--XTO---23
0856-- 9 ---11
0857-- 4 ---04
0858--CNT---47
0859-- 1 ---01
0860-- UP---27
0861--XFR---67
0862-- 2 ---02
0863-- 7 ---07
0864--X=Y---50
0865-- 0 ---00
0866-- 8 ---10
0867-- 8 ---10
0868-- 1 ---01
0869--XFR---67
0870-- 2 ---02
0871-- 3 ---03
0872--X=Y---50
0873-- 0 ---00
0874-- 8 ---10
0875-- 8 ---10
0876-- 1 ---01
0877--GTO---44
0878-- 9 ---11
0879-- 1 ---01
0880-- 0 ---00
0881-- . ---21
0882-- 7 ---07
0883-- UP---27
0884--XFR---67
0885-- 5 ---05
0886--XFR---67
0887--DIV---35
0888-- 6 ---06
0889-- H ---74
0890-- UP---27
0891-- 3 ---03
0892-- 2 ---02
0893-- X ---36
0894--XFR---67
0895-- 1 ---01
0896-- 2 ---02
0897--X<Y---52
0898--CLX---37
0899--XTO---23
0900-- 2 ---02
0901-- 3 ---03
0902--CLX---37
0903--XTO---23
0904-- 2 ---02
0905-- 5 ---05
0906--GTO---44
0907-- 9 ---11
0908-- 6 ---06
0909-- 6 ---06
0910--CLX---37
0911-- 1 ---01
0912-- 9 ---11
0913--XTO---23
0914-- a ---13
0915-- 1 ---01
0916--XTO---23
0917-- 2 ---02
0918-- 5 ---05
0919--XFR---67
0920--IND---31
0921-- a ---13
0922-- UP---27
0923-- 1 ---01
0924--XTO---23
0925-- + ---33
0926-- a ---13
0927--XFR---67
0928--IND---31
0929-- a ---13
0930--X<Y---52
0931-- 0 ---00
0932-- 9 ---11
0933-- 1 ---01
0934-- 9 ---11
0935-- 6 ---06
0936--XTO---23
0937-- - ---34
0938-- a ---13
0939--XFR---67
0940--IND---31
0941-- a ---13
0942--XFR---67
0943-- - ---34
0944-- 1 ---01
0945-- 2 ---02
0946-- UP---27
0947--XFR---67
0948-- 4 ---04
0949--XFR---67
0950-- - ---34
0951-- 1 ---01
0952-- 2 ---02
0953--DIV---35
0954-- G ---15
0955-- DN---25
0956-- r ---76
0957--XFR---67
0958-- X ---36
0959-- 8 ---10
0960-- UP---27
0961-- 8 ---10
0962--DIV---35
0963--YTO---40
0964-- 7 ---07
0965-- 3 ---03
0966--XFR---67
0967-- 6 ---06
0968-- 5 ---05
0969-- UP---27
0970-- 6 ---06
0971--X<Y---52
```

```
0972-- 1 ---01
0973-- 0 ---00
0974-- 4 ---04
0975-- 4 ---04
0976-- 5 ---05
0977--X<Y---52
0978-- 1 ---01
0979-- 0 ---00
0980-- 3 ---03
0981-- 1 ---01
0982-- 4 ---04
0983--X<Y---52
0984-- 1 ---01
0985-- 0 ---00
0986-- 2 ---02
0987-- 2 ---02
0988-- 3 ---03
0989--X<Y---52
0990-- 1 ---01
0991-- 0 ---00
0992-- 1 ---01
0993-- 6 ---06
0994-- 2 ---02
0995--X<Y---52
0996-- 1 ---01
0997-- 0 ---00
0998-- 0 ---00
0999-- 8 ---10
1000-- . ---21
1001-- 6 ---06
1002-- 6 ---06
1003--GTO---44
1004-- 1 ---01
1005-- 0 ---00
1006-- 4 ---04
1007-- 1 ---01
1008-- . ---21
1009-- 8 ---10
1010-- 5 ---05
1011--GTO---44
1012-- 1 ---01
1013-- 0 ---00
1014-- 4 ---04
1015-- 1 ---01
1016-- 1 ---01
1017--GTO---44
1018-- 1 ---01
1019-- 0 ---00
1020-- 4 ---04
1021-- 1 ---01
1022-- 1 ---01
1023-- . ---21
1024-- 1 ---01
1025-- 8 ---10
1026--GTO---44
1027-- 1 ---01
1028-- 0 ---00
1029-- 4 ---04
1030-- 1 ---01
1031-- 1 ---01
1032-- . ---21
1033-- 4 ---04
1034-- 1 ---01
1035--GTO---44
1036-- 1 ---01
1037-- 0 ---00
1038-- 4 ---04
1039-- 1 ---01
1040-- 2 ---02
1041--XTO---23
1042-- 6 ---06
1043-- 5 ---05
1044--CLX---37
1045-- 3 ---03
1046-- 0 ---00
1047--XTO---23
1048-- 9 ---11
1049-- 9 ---11
1050--XFR---67
1051-- 6 ---06
1052-- UP---27
1053-- 3 ---03
1054-- 5 ---05
1055-- 0 ---00
1056-- 0 ---00
1057--X<Y---52
1058-- 1 ---01
1059-- 1 ---01
1060-- 7 ---07
1061-- 7 ---07
1062-- 2 ---02
1063--EEX---26
1064-- 3 ---03
1065--X<Y---52
1066-- 1 ---01
1067-- 1 ---01
1068-- 4 ---04
1069-- 8 ---10
1070-- 5 ---05
1071-- 0 ---00
1072--XTO---23
1073-- 9 ---11
1074-- 9 ---11
1075--EEX---26
1076-- 3 ---03
1077--X<Y---52
1078-- 1 ---01
1079-- 1 ---01
1080-- 3 ---03
1081-- 5 ---05
1082-- 5 ---05
1083-- 0 ---00
1084-- 0 ---00
1085--X<Y---52
1086-- 1 ---01
1087-- 1 ---01
1088-- 2 ---02
1089-- 2 ---02
1090--EEX---26
1091-- 2 ---02
1092--X<Y---52
1093-- 1 ---01
1094-- 1 ---01
1095-- 0 ---00
1096-- 9 ---11
1097-- . ---21
1098-- 2 ---02
1099-- UP---27
1100-- . ---21
1101-- 8 ---10
1102-- 3 ---03
1103--CHS---32
1104--GTO---44
1105-- 1 ---01
1106-- 1 ---01
1107-- 6 ---06
1108-- 9 ---11
1109-- . ---21
1110-- 1 ---01
1111-- 8 ---10
1112-- UP---27
1113-- 2 ---02
1114-- . ---21
1115-- 0 ---00
1116-- 6 ---06
1117--GTO---44
1118-- 1 ---01
1119-- 1 ---01
1120-- 6 ---06
1121-- 9 ---11
1122-- . ---21
1123-- 1 ---01
1124-- 7 ---07
1125-- UP---27
1126-- 1 ---01
1127-- . ---21
1128-- 9 ---11
1129-- 7 ---07
1130--GTO---44
1131-- 1 ---01
1132-- 1 ---01
1133-- 6 ---06
```

```
1134-- 9 ---11
1135-- . ---21
1136-- 1 ---01
1137-- 9 ---11
1138-- UP---27
1139-- 2 ---02
1140-- . ---21
1141-- 0 ---00
1142-- 9 ---11
1143--GTO---44
1144-- 1 ---01
1145-- 1 ---01
1146-- 6 ---06
1147-- 9 ---11
1148-- . ---21
1149-- 2 ---02
1150-- 8 ---10
1151-- UP---27
1152-- 8 ---10
1153-- . ---21
1154-- 2 ---02
1155-- 1 ---01
1156--GTO---44
1157-- 1 ---01
1158-- 1 ---01
1159-- 6 ---06
1160-- 9 ---11
1161-- . ---21
1162-- 3 ---03
1163-- 5 ---05
1164-- UP---27
1165-- 7 ---07
1166-- . ---21
1167-- 1 ---01
1168-- 2 ---02
1169--XTO---23
1170-- 6 ---06
1171-- 6 ---06
1172--YTO---40
1173-- 6 ---06
1174-- 7 ---07
1175--XFR---67
1176-- 6 ---06
1177-- UP---27
1178--EEX---26
1179-- 3 ---03
1180--DIV---35
1181-- DN---25
1182--XSQ---12
1183-- UP---27
1184--YTO---40
1185-- a ---13
1186-- . ---21
1187-- 1 ---01
1188-- X ---36
1189-- 1 ---01
1190--XFR---67
1191-- + ---33
1192-- a ---13
1193--DIV---35
1194-- a ---13
1195-- UP---27
1196-- 4 ---04
1197-- 0 ---00
1198-- X ---36
1199-- 4 ---04
1200-- 1 ---01
1201-- 0 ---00
1202-- 0 ---00
1203--XFR---67
1204-- + ---33
1205-- a ---13
1206--DIV---35
1207-- DN---25
1208-- + ---33
1209--EEX---26
1210--CHS---32
1211-- 3 ---03
1212-- X ---36
1213--YTO---40
1214-- 7 ---07
1215-- 8 ---10
1216-- . ---21
1217-- 1 ---01
1218-- 2 ---02
1219--XTO---23
1220-- 8 ---10
1221-- 2 ---02
1222-- . ---21
1223-- 2 ---02
1224-- 5 ---05
1225--XTO---23
1226-- 8 ---10
1227-- 3 ---03
1228-- . ---21
1229-- 3 ---03
1230-- 8 ---10
1231--XTO---23
1232-- 8 ---10
1233-- 4 ---04
1234-- . ---21
1235-- 5 ---05
1236-- 2 ---02
1237--XTO---23
1238-- 8 ---10
1239-- 5 ---05
1240-- . ---21
1241-- 6 ---06
1242-- 7 ---07
1243--XTO---23
1244-- 8 ---10
1245-- 6 ---06
1246-- . ---21
1247-- 8 ---10
1248-- 4 ---04
1249--XTO---23
1250-- 0 ---00
1251-- 8 ---10
1252-- 7 ---07
1253-- 1 ---01
1254-- . ---21
1255-- 0 ---00
1256-- 4 ---04
1257--XTO---23
1258-- 0 ---00
1259-- 8 ---10
1260-- 8 ---10
1261-- 1 ---01
1262-- . ---21
1263-- 2 ---02
1264-- 8 ---10
1265--XTO---23
1266-- 0 ---00
1267-- 8 ---10
1268-- 9 ---11
1269-- 1 ---01
1270-- . ---21
1271-- 6 ---06
1272-- 4 ---04
1273--XTO---23
1274-- 9 ---11
1275-- 0 ---00
1276--CNT---47
1277-- 2 ---02
1278--EEX---26
1279-- 3 ---03
1280--XTO---23
1281-- 9 ---11
1282-- 6 ---06
1283--XTO---23
1284-- 0 ---00
1285-- 9 ---11
1286-- 7 ---07
1287-- 1 ---01
1288--XTO---23
1289-- 3 ---03
1290--XTO---23
1291-- 9 ---11
1292-- 8 ---10
1293--XTO---23
1294-- 8 ---10
1295-- 0 ---00
```

```
1296-- UP---27
1297--XFR---67
1298-- 2 ---02
1299-- 6 ---06
1300--X=Y---50
1301-- 1 ---01
1302-- 3 ---03
1303-- 3 ---03
1304-- 4 ---04
1305--XFR---67
1306-- 5 ---05
1307-- UP---27
1308--XFR---67
1309-- 2 ---02
1310-- 2 ---02
1311--X>Y---53
1312-- 1 ---01
1313-- 3 ---03
1314-- 2 ---02
1315-- 9 ---11
1316--XFR---67
1317-- 5 ---05
1318-- UP---27
1319--XFR---67
1320-- 1 ---01
1321-- 8 ---10
1322--DIV---35
1323-- DN---25
1324-- L ---72
1325-- N ---73
1326--XTO---23
1327-- 6 ---06
1328-- 8 ---10
1329--XFR---67
1330-- 6 ---06
1331-- 8 ---10
1332--XTO---23
1333-- 7 ---07
1334--CLX---37
1335--XTO---23
1336-- 7 ---07
1337-- 7 ---07
1338-- π ---56
1339-- UP---27
1340-- 2 ---02
1341--DIV---35
1342--YTO---40
1343-- 9 ---11
1344-- 2 ---02
1345--XFR---67
1346-- 9 ---11
1347-- 2 ---02
1348-- UP---27
1349--XFR---67
```

```
1350-- 7 ---07
1351--X<Y---52
1352-- 1 ---01
1353-- 3 ---03
1354-- 6 ---06
1355-- 1 ---01
1356-- 1 ---01
1357--XTO---23
1358-- + ---33
1359-- 8 ---10
1360-- 0 ---00
1361--XFR---67
1362-- 9 ---11
1363-- 6 ---06
1364--XTO---23
1365-- + ---33
1366-- 7 ---07
1367-- 7 ---07
1368--XFR---67
1369-- 1 ---01
1370-- 6 ---06
1371-- UP---27
1372--XFR---67
1373-- 4 ---04
1374-- - ---34
1375-- 3 ---03
1376--DIV---35
1377--YTO---40
1378-- b ---14
1379--XFR---67
1380-- 1 ---01
1381-- 6 ---06
1382-- UP---27
1383-- 2 ---02
1384-- X ---36
1385--XFR---67
1386-- 4 ---04
1387-- - ---34
1388-- 3 ---03
1389--DIV---35
1390--YTO---40
1391-- a ---13
1392-- DN---25
1393--DIV---35
1394--XFR---67
1395-- 7 ---07
1396-- 7 ---07
1397-- X ---36
1398--XFR---67
1399-- 8 ---10
1400-- 0 ---00
1401--DIV---35
1402-- b ---14
1403--XEY---30
```

```
1404--DIV---35
1405-- DN---25
1406-- L ---72
1407-- O ---71
1408--XTO---23
1409-- 9 ---11
1410-- 2 ---02
1411-- UP---27
1412--XFR---67
1413-- 7 ---07
1414-- 9 ---11
1415-- X ---36
1416--XFR---67
1417-- 9 ---11
1418-- 9 ---11
1419--X<Y---52
1420--CNT---47
1421--XEY---30
1422--CNT---47
1423--CNT---47
1424--XFR---67
1425-- 6 ---06
1426-- 7 ---07
1427-- X ---36
1428--XFR---67
1429-- 6 ---06
1430-- 6 ---06
1431-- + ---33
1432--XFR---67
1433-- 6 ---06
1434-- 5 ---05
1435-- X ---36
1436--XFR---67
1437-- 8 ---10
1438-- 0 ---00
1439-- X ---36
1440--YTO---40
1441-- b ---14
1442--XFR---67
1443-- 7 ---07
1444-- 7 ---07
1445-- UP---27
1446--XFR---67
1447-- 9 ---11
1448-- 2 ---02
1449-- N ---73
1450--DIV---35
1451-- DN---25
1452-- UP---27
1453--GTO---44
1454--S/R---77
1455-- 3 ---03
1456--RUP---22
1457--XEY---30
```

```
1458--XFR---67
1459-- 7 ---07
1460-- 8 ---10
1461-- X ---36
1462-- DN---25
1463-- + ---33
1464-- b ---14
1465-- + ---33
1466-- 6 ---06
1467-- - ---34
1468--YTO---40
1469-- 7 ---07
1470-- 4 ---04
1471--CLX---37
1472-- UP---27
1473--XFR---67
1474-- 2 ---02
1475-- 3 ---03
1476--X=Y---50
1477-- 1 ---01
1478-- 5 ---05
1479-- 6 ---06
1480-- 0 ---00
1481--XFR---67
1482-- 7 ---07
1483-- 8 ---10
1484-- UP---27
1485--XFR---67
1486-- 7 ---07
1487-- 2 ---02
1488-- + ---33
1489--XFR---67
1490-- 7 ---07
1491-- 7 ---07
1492-- X ---36
1493-- UP---27
1494--XFR---67
1495-- 7 ---07
1496-- 0 ---00
1497--X<Y---52
1498-- 1 ---01
1499-- 5 ---05
1500-- 1 ---01
1501-- 6 ---06
1502-- DN---25
1503--GTO---44
1504--S/R---77
1505-- 3 ---03
1506-- DN---25
1507-- + ---33
1508--YTO---40
1509-- 7 ---07
1510-- 5 ---05
1511--GTO---44
1512-- 1 ---01
1513-- 5 ---05
1514-- 3 ---03
1515-- 5 ---05
1516-- DN---25
1517--GTO---44
1518--S/R---77
1519-- 1 ---01
1520-- 0 ---00
1521-- DN---25
1522-- + ---33
1523--XFR---67
1524-- 7 ---07
1525-- 0 ---00
1526--GTO---44
1527--S/R---77
1528-- 1 ---01
1529-- 0 ---00
1530-- DN---25
1531-- + ---33
1532--YTO---40
1533-- 7 ---07
1534-- 5 ---05
1535--XFR---67
1536-- 7 ---07
1537-- 7 ---07
1538-- UP---27
1539--XFR---67
1540-- 6 ---06
1541-- 9 ---11
1542--X>Y---53
1543-- 1 ---01
1544-- 5 ---05
1545-- 5 ---05
1546-- 6 ---06
1547--XFR---67
1548-- 7 ---07
1549-- 1 ---01
1550-- X ---36
1551-- DN---25
1552-- + ---33
1553--YTO---40
1554-- 7 ---07
1555-- 5 ---05
1556--GTO---44
1557--S/R---77
1558-- 1 ---01
1559-- 7 ---07
1560--CLX---37
1561-- UP---27
1562--XFR---67
1563-- 2 ---02
1564-- 7 ---07
1565--X=Y---50
1566-- 1 ---01
1567-- 6 ---06
1568-- 4 ---04
1569-- 1 ---01
1570--XFR---67
1571-- 9 ---11
1572-- 5 ---05
1573-- r ---76
1574-- UP---27
1575--XFR---67
1576-- 6 ---06
1577-- 9 ---11
1578-- UP---27
1579-- 2 ---02
1580--DIV---35
1581-- DN---25
1582-- + ---33
1583--XFR---67
1584-- 7 ---07
1585-- 7 ---07
1586--X<Y---52
1587-- 1 ---01
1588-- 6 ---06
1589-- 0 ---00
1590-- 0 ---00
1591-- 0 ---00
1592--XTO---23
1593-- 2 ---02
1594-- 7 ---07
1595--GTO---44
1596-- 1 ---01
1597-- 5 ---05
1598-- 6 ---06
1599-- 0 ---00
1600--XFR---67
1601-- 1 ---01
1602-- 2 ---02
1603-- UP---27
1604--XFR---67
1605-- 4 ---04
1606--X<Y---52
1607--XFR---67
1608-- 6 ---06
1609-- 4 ---04
1610--CNT---47
1611--XSQ---12
1612-- UP---27
1613-- 9 ---11
1614--DIV---35
1615--XFR---67
1616-- 7 ---07
1617-- 7 ---07
1618--XSQ---12
1619-- + ---33
```

```
1620-- DN---25
1621-- r ---76
1622-- UP---27
1623--GTO---44
1624--S/R---77
1625-- 3 ---03
1626--RUP---22
1627--XEY---30
1628--XFR---67
1629-- 7 ---07
1630-- 8 ---10
1631-- X ---36
1632-- DN---25
1633-- + ---33
1634--YTO---40
1635-- 7 ---07
1636-- 5 ---05
1637--GTO---44
1638--S/R---77
1639-- 1 ---01
1640-- 7 ---07
1641--CLX---37
1642-- UP---27
1643--XFR---67
1644-- 2 ---02
1645-- 6 ---06
1646--X=Y---50
1647-- 1 ---01
1648-- 8 ---10
1649-- 2 ---02
1650-- 7 ---07
1651--XFR---67
1652-- 7 ---07
1653-- 8 ---10
1654-- UP---27
1655--XFR---67
1656-- 7 ---07
1657-- 7 ---07
1658-- X ---36
1659--GTO---44
1660--S/R---77
1661-- 3 ---03
1662-- DN---25
1663-- + ---33
1664--YTO---40
1665-- 7 ---07
1666-- 5 ---05
1667--XFR---67
1668-- 7 ---07
1669-- 7 ---07
1670-- UP---27
1671--XFR---67
1672-- 9 ---11
1673-- 3 ---03
1674--X>Y---53
1675-- 1 ---01
1676-- 8 ---10
1677-- 2 ---02
1678-- 3 ---03
1679--XFR---67
1680-- 9 ---11
1681-- 4 ---04
1682--X<Y---52
1683-- 1 ---01
1684-- 7 ---07
1685-- 9 ---11
1686-- 8 ---10
1687--XFR---67
1688-- - ---34
1689-- 9 ---11
1690-- 3 ---03
1691--XTO---23
1692-- a ---13
1693-- UP---27
1694-- 1 ---01
1695-- 0 ---00
1696--DIV---35
1697--YTO---40
1698-- 9 ---11
1699-- 6 ---06
1700--CNT---47
1701-- 1 ---01
1702-- UP---27
1703--XFR---67
1704-- 3 ---03
1705--X>Y---53
1706-- 1 ---01
1707-- 7 ---07
1708-- 2 ---02
1709-- 4 ---04
1710--XFR---67
1711-- 9 ---11
1712-- 3 ---03
1713--XTO---23
1714-- 7 ---07
1715-- 7 ---07
1716--YTO---40
1717-- + ---33
1718-- 3 ---03
1719--GTO---44
1720-- 1 ---01
1721-- 3 ---03
1722-- 4 ---04
1723-- 6 ---06
1724--CHS---32
1725-- 4 ---04
1726-- . ---21
1727-- 5 ---05
1728--EEX---26
1729--CHS---32
1730-- 4 ---04
1731-- UP---27
1732-- a ---13
1733-- X ---36
1734-- 1 ---01
1735-- 5 ---05
1736-- . ---21
1737-- 5 ---05
1738-- + ---33
1739-- DN---25
1740--XSQ---12
1741--1/X---17
1742-- UP---27
1743-- . ---21
1744-- 3 ---03
1745-- 6 ---06
1746-- X ---36
1747--YTO---40
1748-- b ---14
1749--XFR---67
1750-- 7 ---07
1751-- 7 ---07
1752-- UP---27
1753--XFR---67
1754-- 9 ---11
1755-- 3 ---03
1756-- - ---34
1757-- DN---25
1758--XEY---30
1759-- r ---76
1760-- X ---36
1761-- a ---13
1762--DIV---35
1763-- . ---21
1764-- 1 ---01
1765-- 8 ---10
1766--DIV---35
1767-- DN---25
1768--XEY---30
1769-- UP---27
1770-- DN---25
1771--DIV---35
1772-- DN---25
1773-- X ---36
1774--RUP---22
1775--RUP---22
1776--XEY---30
1777--CHS---32
1778-- 2 ---02
1779--DIV---35
1780-- DN---25
1781-- J ---75
```

```
1782-- X ---36
1783--YTO---40
1784-- - ---34
1785-- 7 ---07
1786-- 5 ---05
1787--CNT---47
1788-- 1 ---01
1789--XTO---23
1790-- + ---33
1791-- 9 ---11
1792-- 8 ---10
1793--GTO---44
1794-- 1 ---01
1795-- 8 ---10
1796-- 2 ---02
1797-- 2 ---02
1798-- 1 ---01
1799--XTO---23
1800-- 9 ---11
1801-- 8 ---10
1802--XTO---23
1803-- 3 ---03
1804--CNT---47
1805--XFR---67
1806-- 9 ---11
1807-- 7 ---07
1808--XTO---23
1809-- 9 ---11
1810-- 6 ---06
1811--XFR---67
1812-- 8 ---10
1813--XTO---23
1814-- + ---33
1815-- 9 ---11
1816-- 3 ---03
1817--XFR---67
1818-- 9 ---11
1819--XTO---23
1820-- + ---33
1821-- 9 ---11
1822-- 4 ---04
1823--GTO---44
1824--S/R---77
1825-- 1 ---01
1826-- 7 ---07
1827--CLX---37
1828-- UP---27
1829--XFR---67
1830-- 2 ---02
1831-- 5 ---05
1832--X=Y---50
1833-- 1 ---01
1834-- 8 ---10
1835-- 6 ---06
1836-- 8 ---10
1837--XFR---67
1838-- 7 ---07
1839-- 7 ---07
1840--GTO---44
1841--S/R---77
1842-- 1 ---01
1843-- 0 ---00
1844--XFR---67
1845-- 7 ---07
1846-- 3 ---03
1847--GTO---44
1848--S/R---77
1849-- 1 ---01
1850-- 0 ---00
1851-- DN---25
1852-- + ---33
1853--XFR---67
1854-- 7 ---07
1855-- 8 ---10
1856--XFR---67
1857-- X ---36
1858-- 7 ---07
1859-- 7 ---07
1860-- + ---33
1861--YTO---40
1862-- 7 ---07
1863-- 5 ---05
1864--GTO---44
1865--S/R---77
1866-- 1 ---01
1867-- 7 ---07
1868--XFR---67
1869-- 7 ---07
1870-- 4 ---04
1871--CHS---32
1872-- UP---27
1873--XFR---67
1874-- 7 ---07
1875-- 7 ---07
1876--FMT---42
1877-- 1 ---01
1878-- UP---27
1879--FMT---42
1880-- 1 ---01
1881-- 4 ---04
1882-- 5 ---05
1883-- 0 ---00
1884--XTO---23
1885-- a ---13
1886--XFR---67
1887-- 6 ---06
1888-- 1 ---01
1889-- UP---27
1890--XFR---67
1891-- 7 ---07
1892-- 4 ---04
1893-- - ---34
1894--YTO---40
1895-- 7 ---07
1896-- 6 ---06
1897--XFR---67
1898-- 6 ---06
1899-- 2 ---02
1900--DIV---35
1901-- G ---15
1902--YTO---40
1903-- 0 ---00
1904--CLX---37
1905--X=Y---50
1906-- 1 ---01
1907-- 9 ---11
1908-- 8 ---10
1909-- 8 ---10
1910-- 9 ---11
1911-- 5 ---05
1912--XTO---23
1913-- a ---13
1914-- 8 ---10
1915-- 9 ---11
1916--XTO---23
1917-- b ---14
1918--XFR---67
1919-- 0 ---00
1920-- UP---27
1921--XFR---67
1922-- 9 ---11
1923-- 0 ---00
1924--X>Y---53
1925-- 1 ---01
1926-- 9 ---11
1927-- 3 ---03
1928-- 8 ---10
1929--EEX---26
1930-- 2 ---02
1931--XTO---23
1932-- a ---13
1933--GTO---44
1934-- 1 ---01
1935-- 9 ---11
1936-- 7 ---07
1937-- 1 ---01
1938--XFR---67
1939--IND---31
1940-- b ---14
1941-- UP---27
1942--XFR---67
1943-- 0 ---00
```

```
1944--X>Y---53
1945-- 1 ---01
1946-- 9 ---11
1947-- 7 ---07
1948-- 1 ---01
1949-- 1 ---01
1950--XTO---23
1951-- - ---34
1952-- b ---14
1953-- 5 ---05
1954--XTO---23
1955-- - ---34
1956-- a ---13
1957-- b ---14
1958-- UP---27
1959-- 8 ---10
1960-- 1 ---01
1961--X=Y---50
1962-- 1 ---01
1963-- 9 ---11
1964-- 7 ---07
1965-- 1 ---01
1966--GTO---44
1967-- 1 ---01
1968-- 9 ---11
1969-- 3 ---03
1970-- 8 ---10
1971-- 0 ---00
1972-- UP---27
1973--XFR---67
1974-- 7 ---07
1975-- 6 ---06
1976--X>Y---53
1977-- 1 ---01
1978-- 9 ---11
1979-- 8 ---10
1980-- 8 ---10
1981--EEX---26
1982-- 2 ---02
1983-- UP---27
1984-- a ---13
1985-- - ---34
1986--YTO---40
1987-- a ---13
1988--CHS---32
1989-- 2 ---02
1990-- 4 ---04
1991-- 0 ---00
1992-- UP---27
1993-- a ---13
1994-- + ---33
1995--XFR---67
1996-- 7 ---07
1997-- 7 ---07
1998--FMT---42
1999-- 1 ---01
2000-- UP---27
2001--FMT---42
2002-- 1 ---01
2003-- 4 ---04
2004--XFR---67
2005-- 7 ---07
2006-- 7 ---07
2007-- UP---27
2008--XFR---67
2009-- 6 ---06
2010-- 3 ---03
2011--X>Y---53
2012-- 1 ---01
2013-- 3 ---03
2014-- 4 ---04
2015-- 5 ---05
2016--END---46
```

PEAPS

FORTRAN Program Listing

```
C
C     PEAPS (FORTRAN VERSION)
C
      DIMENSION  HEAD(20), D(15), T(15), SALIN(15), S(15)
      DIMENSION  SGRAD(15), CD(6), CS(6), PR(13), X(8)
      DIMENSION  IH(6)
      INTEGER * 2  IBUF(61, 121)
      DATA X/.12,.25,.38,.52,.67,.84,1.06,1.28/
      INTEGER * 2  IB/'  '/
      INTEGER * 2  IDOT/'. '/
      INTEGER * 2  ISTAR/'* '/
      PI = 3.141592
      RAD = PI / 180.0
   90 DO 91 I = 1, 6
      CD(I) = 0.0
   91 CS(I) = 0.0
C
C     READ AND PRINT HEADING CARD (80 COLUMNS MAX)
C
      READ (5, 900, END = 9999) HEAD
  900 FORMAT (20A4)
      WRITE (6, 901) HEAD
  901 FORMAT (1H1, 20A4)
C
C     READ AND PRIMT INPUT DATA CARDS
C
      READ (5, 902) NPTS, MODE, IBT, IWH, ISS, IFOM, SD, RD,
     *              SF
  902 FORMAT (6I5, 3F10.2)
      FOM = FLOAT(IFOM)
      SS = FLOAT(ISS)
      WRITE (6, 903) NPTS, MODE, IBT, IWH, ISS, IFOM, SD,
     *               RD, SF
  903 FORMAT (1H0, 22HNUMBER OF SSP POINTS =, I5//
     *        19H RAY PLOTTER MODE =, I5 //14H BOTTOM TYPE =,
     *         I5 //14H WAVE HEIGHT =, I5, 3H FT //
     *        15H SYSTEM SIGMA =, I5 //6H FOM =, I5 //
     *        13H SOURCE DEPTH , F10.2, 3H FT //
     *        15H RECEIVER DEPTH , F10.2, 3H FT //
     *        17H SOURCE FREQUENCY , F10.2, 3H HZ )
      WRITE (6, 901) HEAD
      WRITE (6, 904)
  904 FORMAT (1H0,5X,5HPOINT,1X,5HDEPTH,4X, 11HTEMPERATURE,
     *         1X, 8HSALINITY, 1X, 11HSOUND SPEED, 1X,
     *         8HGRADIENT)
C
C     SPEED OF SOUND PROGRAM
C
      DO 102 I = 1, NPTS
      READ (5, 905) D(I), T(I), SALIN(I)
  905 FORMAT (3F10.2)
      WRITE (6, 906) I, D(I), T(I), SALIN(I)
  906 FORMAT (1H0, I10, 3F10.2)
      T(I) = (T(I) - 32.0) * 5.0 / 9.0
      D(I) = D(I) * 0.3048
      D2 = D(I) * D(I)
      D4 = D2 * D2
      T2 = T(I) * T(I)
      T3 = T2 * T(I)
      S1 = SALIN(I) - 35.0
      S2 = S1 * S1
      S(I) = 1449.3 + 1.5848E-2 * D(I) + 1.572E-7 * D2
     *       - 3.46E-16 * D4 + 4.587 * T(I) - 5.356E-2 * T2
     *       + 2.604E-4 * T3 + 1.19 * S1 + 9.6E-2 * S2
     *       + 1.534E-4 * T2 * D(I) - 7.19E-9 * T(I) * D2
     *       - 1.2E-2 * S1 * T(2)
      S(I) = S(I) / 0.3048
      D(I) = D(I) / 0.3048
      WRITE (6, 907) S(I)
  907 FORMAT (1H-, 40X, F10.2)
      IF (I .GT. 1) GO TO 100
      SGRAD(1) = 0.0
```

```
      GO TO 101
  100 J = I - 1
      SGRAD(I) = (S(I) - S(J)) / (D(I) - D(J))
  101 WRITE (6, 908) SGRAD(I)
  908 FORMAT (1H0, 50X, F10.4)
  102 CONTINUE
C
C     SPEED OF SOUND PROFILE CRITICAL POINTS PROGRAM
C
      I = 0
      IFLAG = 0
      IRUN = -1
      J = 1
      K = 2
      NG = 0
      NTEST = -1
  103 I = I + 1
      J = J + 1
      NTEST = NTEST + 1
  104 IRUN = IRUN + 1
      IF (J .GT. NPTS) GO TO 113
      IF (S(I) .EQ. S(J)) GO TO 103
      IF (NTEST .EQ. 0) GO TO 105
      NTEST = 0
      CS(K) = S(I)
      CD(K) = D(I)
      K = K + 1
      NG = NG + 1
      IF (S(J) .LT. S(I)) GO TO 105
      IFLAG = 1
  105 IF (IFLAG .EQ. 1) GO TO 110
  106 IF (S(J) .LT. S(I)) GO TO 108
      IF (IRUN .EQ. 0) GO TO 107
      CS(K) = S(I)
      CD(K) = D(I)
      K = K + 1
      NG = NG + 1
      IFLAG = 1
      GO TO 104
  107 IFLAG = 1
      GO TO 104
  108 IF (IRUN .GT. 0) GO TO 109
      CS(K) = S(I)
      CD(K) = D(I)
      K = K + 1
      NG = NG + 1
  109 IRUN = IRUN + 1
      I = I + 1
      J = J + 1
      IF (J .GT. NPTS) GO TO 112
      GO TO 106
  110 IFLAG = 0
      IF (S(J) .GT. S(I)) GO TO 111
      CS(K) = S(I)
      CD(K) = D(I)
      K = K + 1
      NG = NG + 1
      GO TO 104
  111 I = I + 1
      J = J + 1
      IRUN = IRUN + 1
      IF (J .LE. NPTS) GO TO 110
  112 CS(K) = S(I)
      CD(K) = D(I)
      NG = NG + 1
  113 CS(1) = S(1)
      CD(1) = D(1)
      CS(6) = S(NPTS)
      CD(6) = D(NPTS)
C
C     SOUND SPEED PROFILE PROGRAM
C
```

```
      WRITE (6, 901) HEAD
      WRITE (6, 909)
  909 FORMAT (1H0, 35HSOUND SPEED PROFILE CRITICAL POINTS //
     *            5X, 6H DEPTH, 4X, 14HSPEED OF SOUND )
      DO 114 I = 1, 6
  114 WRITE (6, 910) CD(I), CS(I)
  910 FORMAT (1H0, 2F10.2)
      DO 115 I = 1, 61
      DO 115 J = 1, 121
  115 IBUF(I, J) = IB
      WRITE (6, 901) HEAD
      WRITE (6, 911)
  911 FORMAT (1H0, 37HSPEED OF SOUND (FT/SEC) VS DEPTH (FT))
      SMIN = CS(1)
      SMAX = CS(6)
      DO 116 I = 1, 6
      IF (CS(I) .EQ. 0.0) GO TO 116
      IF (CS(I) .LT. SMIN) SMIN = CS(I)
      IF (CS(I) .GT. SMAX) SMAX = CS(I)
  116 CONTINUE
      PRI = (SMAX - SMIN) / 12.0
      PR(1) = SMIN
      V = PR(1)
      DO 117 I = 2, 13
      V = V + PRI
  117 PR(I) = V
      WRITE (6, 912) (PR(I), I = 1, 13)
  912 FORMAT (F8.1, 12F10.1)
      DO 121 I = 1, 61
      IF (MOD ((I-1), 10) .EQ. 0) GO TO 119
      DO 118 J = 1, 121, 10
  118 IBUF(I, J) = IDOT
      GO TO 121
  119 DO 120 J = 1, 121
  120 IBUF(I, J) = IDOT
  121 CONTINUE
      WRITE (6, 913) (IBUF(3, J), J = 1, 121)
  913 FORMAT (1H , 5X, 121A1)
      PRI = (PR(13) - PR(1)) / 120.0
      PPDI = D(NPTS) / 60.0
      J = NPTS - 1
      DO 123 I = 1, J
      PPD = D(I)
      PPR = S(I)
      PPRI = SGRAD(I + 1) * PPDI
  122 IPPD = (PPD / PPDI) + 1.5
      IPPR = (PPR - PR(1)) / PRI
      IBUF(IPPD, IPPR) = ISTAR
      PPD = PPD + PPDI
      IF (PPD .GT. D(I + 1)) GO TO 123
      PPR = PPR + PPRI
      GO TO 122
  123 CONTINUE
      MND = D(NPTS) / 6.0
      MNDP = 0
      DO 126 I = 1, 61
      IF (I .EQ. 1) GO TO 125
      IF (MOD((I-1), 10) .EQ. 0) GO TO 124
      WRITE (6, 913) (IBUF(I, J), J = 1, 121)
      GO TO 126
  124 MNDP = MNDP + MND
  125 WRITE (6, 914) MNDP, (IBUF(I,J), J = 1, 121)
  914 FORMAT (1H , I5, 121A1)
  126 CONTINUE
C
C     RAY TRACE PROGRAM
C
      IFLAG = 0
      IF (MODE .NE. 2) GO TO 127
C
C     READ IN MODE 2 RAY TRACE EMISSION ANGLES
C
```

```
      READ (5, 905) THMIN, DTH, THMAX
  127 IF (MODE .EQ. 1) GO TO 134
      DO 128 I = 1, 61
      DO 128 J = 1, 121
  128 IBUF (I, J) = IB
      WRITE (6, 901) HEAD
      WRITE (6, 915)
  915 FORMAT (1H0, 24HRANGE (NM) VS DEPTH (FT) )
      PRI = 5.0
      V = -5.0
      DO 129 I = 1, 13
      V = V + PRI
  129 PR(I) = V
      WRITE (6, 912) (PR(I), I = 1, 13)
      DO 133 I = 1, 61
      IF (MOD ((I - 1), 10) .EQ. 0) GO TO  131
      DO 130 J = 1, 121, 10
  130 IBUF(I, J) = IDOT
      GO TO 133
  131 DO 132 J = 1, 121
  132 IBUF(I, J) = IDOT
  133 CONTINUE
      PRI = 3000.0
      RMAX = 360000.0
      WRITE (6, 913) (IBUF(3, J), J = 1, 121)
C
C      CONVERGENCE ZONE TEST
C
      IF (MODE .EQ. 2) GO TO 219
  134 IF (CS(6) .GT. CS(2)) GO TO 136
  135 WRITE (6, 916)
  916 FORMAT (1H0, 19HNO CONVERGENCE ZONE )
      ICZ = 0
      GO TO 139
  136 M = 2
  137 M = M + 1
      IF (CS(M) .EQ. 0.0) GO TO 135
      IF (CS(2) .GT. CS(M)) GO TO 138
      IF (M .EQ. 6) GO TO 135
      GO TO 137
  138 ICZ = 1
  139 M = 0
  200 M = M + 1
      IF ( SD .GE. D(M)) GO TO 200
      SV = ((SD - D(M - 1)) * SGRAD(M)) + S(M - 1)
      THP = (2.0 - (2.0 * SV / CS(2))) ** 0.5
      THPP = (ABS (2.0 - (2.0 * SV / CS(6)))) ** 0.5
      IF (ICZ .EQ. 0) GO TO 227
      THMIN = THPP
      IPLOT = 1
      ISR = 1
  201 IF (MODE .EQ. 1) IPLOT = 0
      TH = THMIN
      Z = SD
      R = 0.0
  202 M = 0
  203 M = M + 1
      IF (D(M) .GT. Z) GO TO 204
      IF (M .EQ. NPTS) GO TO 208
      GO TO 203
  204 IF (Z .LT. 0.0) GO TO 208
  205 RADIUS = (-SGRAD(M) * (1.0 - ((TH * TH) / 2.0))) /
     *         ((SGRAD(M) * (Z - D(M - 1)) + S(M - 1)))
      DR = 5.0 * ((D(M) - D(M - 1)) ** 0.5)
  206 RDR = DR * RADIUS
      R = R + DR
      Z = Z + ((RADIUS * (DR * DR)) / 2.0) + (TH * DR)
      TH = TH + RDR
      IF (IPLOT .EQ. 0) GO TO 207
      IPPD = (Z / PPDI) + 1.5
      IF (IPPD .GT. 61) GO TO 207
      IPPR = R / PRI
```

```
      IF (IPPR .GT. 121) GO TO 207
      IBUF(IPPD, IPPR) = ISTAR
  207 IF (Z .LT. D(M - 1)) GO TO 202
      IF (D(M) .LT. Z) GO TO 202
      IF (RMAX .GE. R) GO TO 206
  208 GO TO (209, 212, 213, 216, 217, 222, 220), ISR
  209 IF (D(NPTS) .LT. Z) GO TO 210
      IF (IFLAG .EQ. 1) GO TO 211
      THMIN = THMIN + (0.5 * RAD)
      IPLOT = 1
      ISR = 1
      GO TO 201
  210 THMIN = THMIN - (0.1 * RAD)
      IPLOT = 0
      IFLAG = 1
      ISR = 1
      GO TO 201
  211 THBB = THMIN
      IFLAG = 0
      ICZ = 1
      IPLOT = 1
      CZMAX = R
      ISR = 2
      GO TO 201
  212 THMIN = THP
      IPLOT = 1
      ISR = 3
      GO TO 201
  213 IF (R .GT. (CZMAX / 2.0)) GO TO 214
      THMIN = THMIN + (0.1 * RAD)
      IPLOT = 0
      ISR = 3
      GO TO 201
  214 IF (R .GT. CZMAX) CZMAX = R
  215 CZMIN = R
      THMIN = THMIN + (0.5 * RAD)
      IPLOT = 1
      ISR = 4
      GO TO 201
  216 IF (R .LT. CZMIN) GO TO 215
      THMIN = THMIN - (0.4 * RAD)
      IPLOT = 0
      ISR = 5
      GO TO 201
  217 IF (R .GT. CZMIN) GO TO 218
      CZMIN = R
      THMIN = THMIN + (0.1 * RAD)
      ISR = 5
      GO TO 201
  218 THMIN = THMIN - (0.1 * RAD)
      IPLOT = 1
      ISR = 6
      GO TO 201
  219 IF (IFLAG .EQ. 1) GO TO 222
      ISR = 7
      GO TO 201
  220 THMIN = THMIN + DTH
      IF (THMIN .LE. THMAX) GO TO 219
      ISR = 1
      GO TO 223
  221 MODE = 1
      GO TO 134
  222 IBB = 1
      CZMIN = CZMIN / 3.0
      CZMAX = CZMAX / 3.0
      IPLOT = 1
      ISR = 2
  223 MNDP = 0
      DO 226 I = 1, 61
      IF (I .EQ. 1) GO TO 225
      IF (MOD((I-1), 10) .EQ. 0) GO TO 224
      WRITE (6, 913) (IBUF(I, J), J = 1, 121)
```

```
      GO TO 226
  224 MNDP = MNDP + MND
  225 WRITE (6, 914) MNDP, (IBUF(I,J), J = 1, 121)
  226 CONTINUE
      GO TO (221, 227), ISR
  227 CONTINUE
C
C     TRANSMISSION LOSS PROGRAM
C
      B = FOM
      IF(80.GE.IFOM) B = 80.0
      IF(100.LE.IFOM) B = 100.0
      B = (B + 15.0) / 20.0
      B = 10.0**B
      IR = B/20000.0
      RMAX = (IR + 1) * 20000
      WRITE (6, 901) HEAD
      WRITE (6, 917)
  917 FORMAT (1H0, 10HRANGE (NM) , 1X, 5HTLOSS , 4X, 4HPDET)
      DO 228 I = 1, 61
      DO 228 J = 1, 121
  228 IBUF(I, J) = IB
      PRI = RMAX / 24000.0
      PR(1) = 0.0
      V = 0.0
      DO 229 I = 2, 13
      V = V + PRI
  229 PR(I) = V
      IPFOM = ((IFOM - 40) / 2)
      DO 233 I = 1, 61
      IF (MOD((I-1), 10) .EQ. 0) GO TO 231
      DO 230 J = 1, 121, 10
      IBUF(I, J) = IDOT
      IF (I .EQ. IPFOM) IBUF(I, J) = ISTAR
  230 CONTINUE
      GO TO 233
  231 DO 232 J = 1, 121
      IBUF(I, J) = IDOT
      IF (I .EQ. IPFOM) IBUF(I, J) = ISTAR
  232 CONTINUE
  233 CONTINUE
      PRI = RMAX / 120.0
      PPDI = 2.0
      IF(CS(2).LT.CS(1)) GO TO 304
      IF(SD.GT.CD(2)) GO TO 303
      IF(RD.GT.CD(2)) GO TO 301
      ISD = 1
      IRAP = 0
      RS = ARCOS(CS(1)/CS(2))*(2.0/3.0)*(CS(1)*(CD(2)-CD(1))
     *      )/(CS(2) - CS(1))
      RT = CD(2)/(6.0*ARCOS(SV/CS(2)))
      SSL = (0.8/RS)*((WH*SF/1000.0)**0.71)
      G = ABS((CS(3)-CS(2))/(CD(3)-CD(2)))
      DFL = 744.0*((SF/1000.0)**(-5.0/3.0))*(G**(-1.0/3.0))*
     *      (CD(2) ** (-3.0))
      GO TO 306
  301 IRAP = 1
      RL2 = CS(2)*(CD(3)-CD(2))/(CS(2)-CS(3))
      IF(SD.GT.CD(2)) GO TO 302
      RL2 = RL2*(RD-CD(2))/4.5
      GO TO 305
  302 RL2 = RL2*(SD-CD(2))/4.5
      GO TO 305
  303 IF(RD.GT.CD(2)) GO TO 304
      GO TO 301
  304 IRAP = 0
  305 ISD = 0
      GO TO 307
  306 IF(NG.EQ.1) DFL = 0.0
  307 IF(ICZ.EQ.1) GO TO 308
      GO TO 310
  308 CZSTRT = CZMIN
```

```
      CZSTOP = CZMAX
      IF(IRAP.EQ.1) GO TO 310
      IF(ISD.EQ.1) GO TO 310
      IDSC = 1
      M = 1
  309 M = M + 1
      IF(CS(M+1).LT.CS(M)) GO TO 309
      RPT = (CZMIN/ 8.0)*((CD(M)-CD(2))/(SD-CD(2)))**0.5
      GO TO 313
  310 FTEST = 32.0 * ((SV / SF) ** 0.7)
      IF(FTEST.GT.CD(2)) GO TO 311
      GO TO 312
  311 ISD = 0
  312 IDSC = 0
  313 IF(6.LT.IBT) GO TO 314
      IF(5.LT.IBT) GO TO 315
      IF(4.LT.IBT) GO TO 316
      IF(3.LT.IBT) GO TO 317
      IF(2.LT.IBT) GO TO 318
      BT = 0.66
      GO TO 319
  314 BT = 2.0
      GO TO 319
  315 BT = 1.41
      GO TO 319
  316 BT = 1.18
      GO TO 319
  317 BT = 1.0
      GO TO 319
  318 BT = 0.85
  319 BLMA = 30.0
      IF(3500.0.LT.SF) GO TO 320
      IF(2000.0.LT.SF) GO TO 321
      BLMA = 50.0
      IF(1000.0.LT.SF) GO TO 322
      IF(500.0.LT.SF) GO TO 323
      IF(100.0.LT.SF) GO TO 324
      B1 = 0.2
      B0 = -0.83
      GO TO 325
  320 B1 = 0.35
      B0 = 7.12
      GO TO 325
  321 B1 = 0.28
      B0 = 8.21
      GO TO 325
  322 B1 = 0.19
      B0 = 2.09
      GO TO 325
  323 B1 = 0.17
      B0 = 1.97
      GO TO 325
  324 B1 = 0.18
      B0 = 2.06
  325 SFKHZ = SF/1000.0
      SFKHZ2 = SFKHZ*SFKHZ
      A = ((0.1*SFKHZ2)/(1.0+SFKHZ2)) + ((40*SFKHZ2)/(4100.0
     *     + SFKHZ2))
      A = A / 1000.0
      ICZRC = 1
      H = 1.0
      DRWRK = 2000.0
      DRPERM = 2000.0
      IF (ICZ .EQ. 1) GO TO 3251
      IF (CS(6) .GT. SV) GO TO 3250
      THP = ARCOS(SV / CS(6))
 3250 THBB = THP
 3251 R = 0.0
      THBL = PI / 2.0
  326 IF(THBB.GT.THBL) H = H + 1.0
      R = R + DRWRK
      THBL = ATAN((R*((CD(6)-SD)/3.0))/
```

```
     *            (H*((2.0*CD(6)-SD)/3.0)))
      THBLA = THBL * (180.0 / PI)
      IF (BLMA .LT. THBLA) THBLA = BLMA
      BL = H * BT * ((THBLA * B1) + B0)
      STL = (20.0*ALOG10(R/COS(THBL)) +
     *     (A*(R/COS(THBL))) + BL - 6.0)
      IF(ISD.EQ.0) GO TO 330
      ISR = 1
      TL = (A + DFL) * R
      IF (RT .LT. R) GO TO 327
      TL = TL + 20.0*ALOG10(R)
      GO TO 328
  327 TL = TL + 10.0*ALOG10(R) + 10.0*ALOG10(RT)
  328 IF (RS .GT. R) GO TO 329
      TL = TL + (SSL * R)
  329 F = (ABS(STL - TL)) / (-10.0)
      AD = 10.0 * (ALOG10(1.0 + (10.0 ** F)))
      IF(STL.LT.TL) TL = STL
      STL = TL - AD
      GO TO (330, 334, 338, 339), ISR
  330 IF(IRAP.EQ.0) GO TO 334
      ISR = 2
      RAPTES = (RL2 ** 0.5) + (RS / 2.0)
      IF(R.LT.RAPTES) GO TO 331
      IRAP = 0
      GO TO 330
  331 IF (SD.LT.RD) GO TO 332
      TL = 20.0*ALOG10((SD*SD + R*R)**0.5) + A*((SD*SD +
     *     R * R) ** 0.5)
      GO TO 333
  332 TL = 20.0*ALOG10((RD*RD + R*R)**0.5) + A*((RD*RD +
     *     R * R) ** 0.5)
  333 GO TO 329
  334 IF(ICZ.EQ.0) GO TO 338
      ISR = 3
      TL = 20.0*ALOG10(R) + A*R
      IF(R.LT.CZSTRT) GO TO 337
      IF(R.GT.CZSTOP) GO TO 336
      IF(ICZRC.EQ.2) GO TO 335
      DRWRK = (CZSTOP - CZSTRT)/10.0
      R = CZSTRT - DRWRK
      ICZRC = 2
      GO TO 326
  335 RANGE = R - CZSTRT
      GCZMAX = 15.5 - 0.0005*(CZSTOP - CZSTRT)
      GB = 0.36 / (GCZMAX*GCZMAX)
      RP = RANGE*(GB**.5) / (0.18*(CZSTOP - CZSTRT))
      GCZ = (RP/GB) * EXP(-(RP*RP) / (2.0*GB))
      TL = TL - GCZ
      GO TO 337
  336 CZSTRT = CZSTRT + CZMIN
      CZSTOP = CZSTOP + CZMAX
      DRWRK = DRPERM
      ICZRC = 1
  337 GO TO 329
  338 IF(IDSC.EQ.0) GO TO 339
      ISR = 4
      TL = 10.0*ALOG10(R) + 10.0*ALOG10(RPT) + A*R
      GO TO 329
  339 PPD = STL
      PPR = R
      IPPD = ((PPD - 40.0) / PPDI) + 1.5
      IF (IPPD .GT. 61) IPPD = 61
      IPPR = (PPR / PRI) + 1.0
      IF (IPPR .GT. 121) IPPR = 121
      IF (IPPD .GT. 60) IPPD = 60
      IBUF(IPPD, IPPR) = ISTAR
C
C     PROBABILITY OF DETECTION PROGRAM
C
      PD = 0.5
      SE = FOM - STL
```

```
      XX = ABS(SE/SS)
      IF(XX.EQ.0.0) GO TO 343
      PD = 0.95
      I = 8
      IF(1.64.LE.XX) GO TO 341
  340 IF(XX.GT.X(I)) GO TO 342
      PD = PD - 0.05
      I = I - 1
      IF(I.EQ.0) GO TO 342
      GO TO 340
  341 PD = 1.0
  342 IF(SE.GT.0.0) GO TO 343
      PD = 1.0 - PD
  343 PPD = 61.0 - (PD * 10.0)
      IPPD = PPD + 0.5
      IF (IPPD .GT. 61) IPPD = 61
      IBUF(IPPD, IPPR) = ISTAR
      RP = R / 2000.0
      WRITE (6, 918) RP, STL, PD
  918 FORMAT (1H0, 3F10.2)
      IF(RMAX.GT.R) GO TO 326
      WRITE (6, 901) HEAD
      WRITE (6, 919)
  919 FORMAT (1H0, 35HTLOSS (DB) ABOVE PDET (PERCENT) VS ,
     *             10HRANGE (NM) )
      WRITE (6, 912) (PR(I), I = 1, 13)
      WRITE (6, 913) (IBUF(3, J), J = 1, 121)
      MNDP = 40
      MND = 20
      DO 347 I = 1, 61
      IF (I .EQ. 1) GO TO 346
      IF (MOD((I-1), 10) .EQ. 0) GO TO 345
      IF (I .GT. 50) GO TO 344
      WRITE (6, 913) (IBUF(I, J), J = 1, 121)
      GO TO 347
  344 IF (I .GT. 52) GO TO 345
      MNDP = 100
      MND = -10
  345 MNDP = MNDP + MND
  346 WRITE (6, 914) MNDP, (IBUF(I,J), J = 1, 121)
  347 CONTINUE
      GO TO 90
 9999 STOP
      END
```

APPENDIX E

PEAPS STORAGE LOCATIONS IN THE HP9810A CALCULATOR

A. The operator enters all angles in degrees. The zero degrees direction for all angles is horizontal to the right. Clockwise angles (down) from the horizontal are to be entered as positive (+) angles. Counter-clockwise angles (up) from the horizontal are to be entered as negative (-) angles.

B. All angles are stored and used in radians. Entered angles are automatically converted from degrees to radians for storage by the program:

$$\text{degrees} = \frac{\pi}{180} * \text{radians}$$

$$\text{radians} = \frac{180}{\pi} * \text{degrees}$$

C. Enter all temperatures in degrees fahrenheit (°F). Temperatures are automatically converted to degrees centigrade (°C) for use in the SSP program:

$$°C = \frac{5}{9} (°F - 32)$$

$$°F = 32 + (\frac{9}{5} * °C)$$

D. Enter depths in feet (ft). Depths are stored in feet and are converted to the required units as needed in the programs:

meters = 0.3048 * feet

feet = meters/0.3048

yards = feet/3.0

nautical miles (NM) = yards/2000 = meters/1852.

E. Ranges are in feet in the ray trace program and are automatically converted to units of yards for use in the transmission loss/probability of detection program.

F. The following pages of program forms indicate the parameter storage locations used in the PEAPS model. The terms listed are defined in the Table of Symbols and throughout the body of the text.

PEAPS (General Storage) REG. a to 58 PAGE 1 OF 3

MATH , PRINTER ALPHA/PLOTTER

X

X

TOTAL PROGRAM STEPS ☐ 500 ☐ 1012 ☒ 2000

TOTAL REGISTERS ☐ 31 ☒ 111

	WRKNG
	WRKNG
0	WRKNG
1	WRKNG
2	WRKNG
3	WRKNG
4	SD
5	SV
6	SF
7	THBB
8	CZMIN
9	CZMAX
10	NPTS
1	CD1
2	CD2
3	CD3
4	CD4
5	CD5
6	CD6
7	CS1
8	CS2
9	CS3
20	CS4
1	CS5
2	CS6
3	ISD
4	IBB
5	IDSC
6	ICZ
7	IRAP
8	D1
9	S1
30	D2
1	S2
2	D3
3	S3
4	D4
5	S4
6	D5
7	S5
8	D6
9	S6
40	D7
1	S7
2	D8
3	S8
4	D9
5	S9
6	D10
7	S10

ALPHA

PEAPS STORAGE (TL/PD) PAGE 3 OF 3

TOTAL PROGRAM STEPS

TOTAL REGISTERS ☐ 51 ☐ 111

60	IWH
61	IFOM
62	ISS
63	RMAX
64	RD
65	IBT
66	BO
67	B1
68	THP
69	RS
70	RT
71	SSL
72	DFL
73	RPT
74	STL
75	TL
76	SE
77	R
78	A
79	$180/\pi$
80	N
81	BB1
82	.12
83	.25
84	.38
85	.52
86	.67
87	.84
88	1.06
89	1.28
90	1.64
91	BB2
92	THBL
93	CZSTRT
94	CZSTOP
95	RL2
96	DRWRK
97	DRPERM
98	ICZRC
99	BMA
100	
101	
102	
103	
104	
105	
106	
107	

NOTE: The values stored in registers 82 to 90 are the 5% points from the lower half of a normal distribution curve.

ALPHA

PEAPS STORAGE (RAY TRACE) - REG. 59 - 75 PAGE 2 OF 3

TOTAL PROGRAM STEPS ☐ 500 ☐ 1012 ☐ 20

TOTAL REGISTERS ☐ 51 ☐ 111

b	
a	
40	
1	
2	
3	
4	
5	
6	
7	
48	D11
9	S11
50	D12
1	S12
2	D13
3	S13
4	D14
5	S14
6	D15
7	S15
8	NG
9	IPLOT
60	MODE
1	RDR
2	0.05°
3	0.5°
4	THMIN
5	DTH
6	THMAX
7	THPP
8	THP
9	RADIUS
70	RP
1	R
2	Z
3	G
4	TH
5	DR
6	
7	
8	
9	
0	
1	
2	
3	
4	
5	
6	
7	

Note: Although the angles shown in registers 62 and 63 are shown in degrees, they are actually stored in radians

ALPHA

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7. Deleted.

8. Deleted.

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